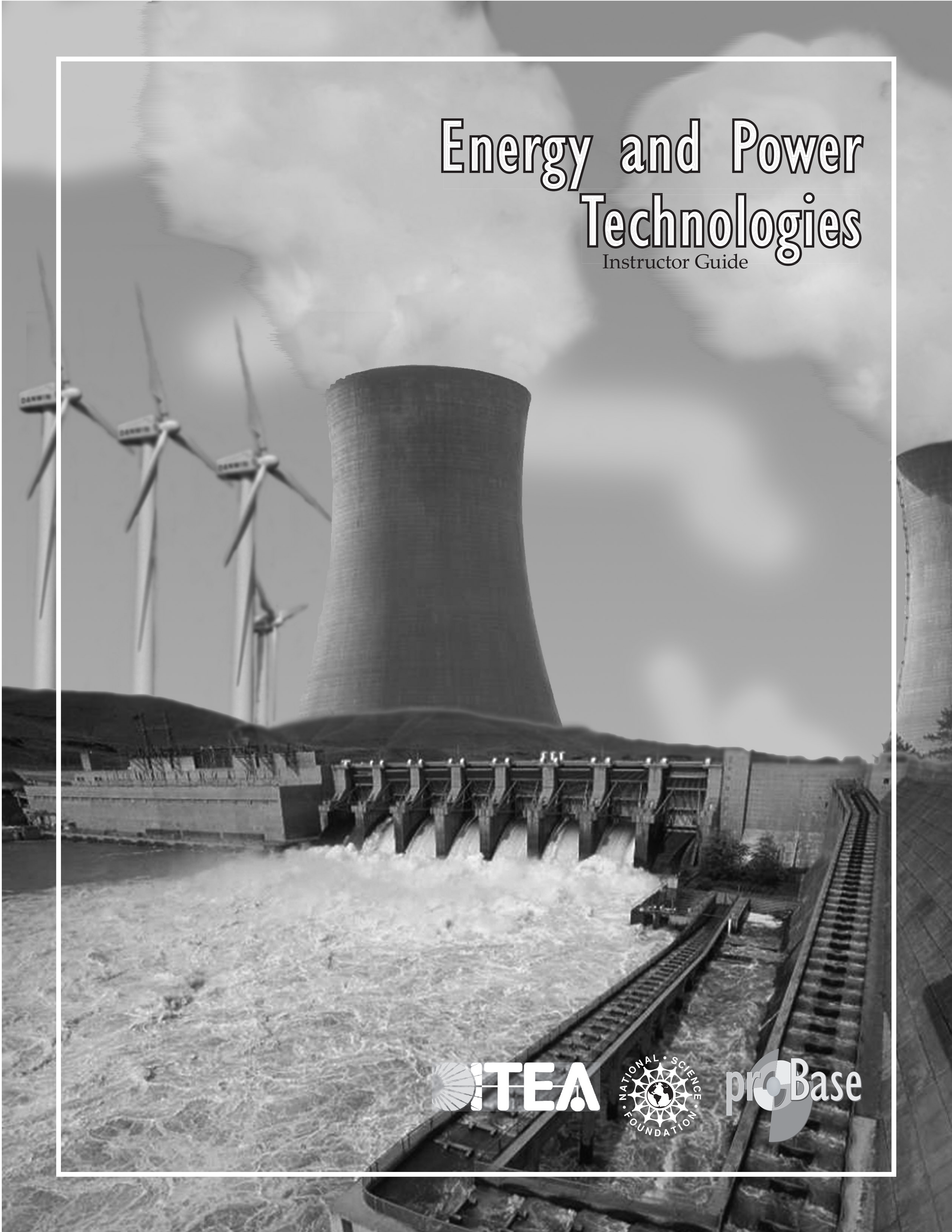
Energy and Power Technologies

Instructor Guide



Acknowledgments

Engaging Technology

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Advanced Technological Education

International Technology Education Association
Center to Advance the Teaching of Technology & Science

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Learning Unit Overview

Learning Unit Purpose

As our nation's economy, society at large, and environment are increasingly influenced by technological innovations, it is imperative that our educational system is able to keep pace and is able to prepare students for highly technical careers. This Project ProBase Learning Unit, titled *Energy and Power Technologies,* is designed to help prepare high school students who plan to go on to community college technical education or university-level engineering programs.

This unit is one of eight Learning Units developed by Project ProBase to address the critical need for upper high school technology education curriculum. The Project ProBase Learning Units utilize hands-on, problem-based activities to introduce fundamental technology concepts related to each context area standard identified in *Standards for Technological Literacy: Content for the Study of Technology* published by the International Technology Education Association.

You may be interested in the other Learning Units developed by Project ProBase:

- *Agriculture and Related Biotechnologies*
- *Construction Technologies*
- *Entertainment and Recreation Technologies*
- *Energy and Power Technologies*
- *Information and Communication Technologies*
- *Manufacturing Technologies*
- *Medical Technologies*
- *Transportation Technologies*

Constructivist-based Teaching and Learning

Each Learning Unit is driven by authentic open-ended problems offering multiple opportunities for students to construct knowledge about the world around them. Constructivism is a learning theory based on the belief that humans learn best when they construct their own knowledge based on their experiences.

One goal of the ProBase Learning Units is to provide a variety of authentic, contextually-based situations that students can use to construct accurate knowledge and develop appropriate skills across the contexts of technology. Constructivist learning is accomplished by providing experiences and opportunities that encourage students to construct accurate knowledge and understanding. Each Learning Unit considers the student a creator of knowledge and assumes that the teacher will facilitate this acquisition of knowledge. This is contrary to the notion that teachers are "dispensers" of knowledge and requires a paradigm shift for some.

As facilitators of learning, ProBase instructors will need to prepare for class in a slightly different way. Students will still need materials and equipment as they engage in activities.

Instructors should review all of the learning cycles in advance so that they know what materials and equipment to gather, as well as what types of demonstrations must be provided. Another important reason for reviewing the learning cycles is to begin thinking about appropriate questions to ask the students. Sample questions are provided in the *Reflection* phase of each learning cycle. However, the instructor may want to go beyond these questions to probe student thinking to find out the technological perspectives students bring to the class. The instructor should ask questions that challenge student thinking and present new ideas that help students create conceptual change.

Connecting the Standards for Technological Literacy: Content for the Study of Technology

Enduring Understandings

Each Learning Unit developed by Project ProBase was developed to address three to four enduring understandings derived from *Standards for Technological Literacy: Content for the Study of Technology* (STL) published by the International Technology Education Association (2000/2002). According to Wiggins and McTighe in *Understanding by Design* (1998, p. 10), an enduring understanding "refers to the big ideas, the important understandings, that we want students to 'get inside of' and retain after they've forgotten many of the details."

In an effort to distill the enduring understandings from the STL, each standard was filtered through the following questions:

- Does the standard represent a big idea having enduring value beyond the classroom?
- Does the standard reside at the heart of the discipline?
- Does the standard require uncoverage of abstract and often misunderstood ideas?
- Does the standard offer potential for engaging students?

This process yielded nine enduring understandings. For a complete list of enduring understandings along with corresponding essential questions, see appendix page AA.

Students will understand:

1. That technological progression is driven by a number of factors, including individual creativity, product and systems innovations, and human wants and needs.
2. That technological development for the solution of a problem in one context can spinoff for use in a variety of often unrelated applications.
3. That technological change can be positive and/or negative and can have intended and/or unforeseen social, cultural, and environmental consequences.
4. How technological systems work, the components of those systems, and how they fit into the larger technological, economic, and social systems.
5. The compelling and controversial issues associated with the acquisition, development, use, and disposal of resources.

6. That the complexities of technological design involve trade-offs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.
7. That technological design is a systematic process used to initiate and refine ideas, solve problems, and maintain products and systems.
8. How technological assessment is used to determine the benefits, limitations, and risks associated with existing and proposed technologies.
9. How to utilize a variety of simple and complex technologies.

Essential Questions

Each enduring understanding must be "unpacked" to be meaningful for learning and instruction. Therefore, each enduring understanding has several essential questions associated with it. The essential questions are addressed through the learning cycles.

Bridge Competencies

In addition to focusing on the enduring understandings derived from STL, each Learning Unit helps to address a set of Bridge Competencies developed in conjunction with a consortium of central Illinois community college partners. Representatives from this consortium reviewed each Learning Unit to identify where the Bridge Competencies were being addressed. Each Learning Unit contains a matrix that reflects which Bridge Competencies are addressed in that specific Learning Unit.

Learning Unit Framework

Each Learning Unit developed by Project ProBase follows a similar format in an effort to be consistent and true to a constructivist-based curriculum.

Preliminary Challenge

Students will be introduced to the Learning Unit through a hands-on activity designed to pique their interest and begin to establish a focus for the Learning Unit.

Primary Challenge

Next, the students are introduced to a robust *Primary Challenge,* which is far too complex to be solved at this point in the unit. Students will be asked to reflect on the knowledge and skills needed to reach a plausible solution to this challenge. This instructor-led discussion happens just before the students are led through a series of four-phase learning cycles designed to develop the knowledge and skills necessary to successfully complete the *Primary Challenge.* Time is provided throughout the nine-week Learning Unit to actually work on a solution to the *Primary Challenge.*

Four-phase Learning Cycles

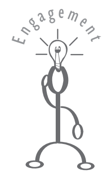
In order to develop plausible solutions for the *Primary Challenge*, students must gain accurate knowledge and appropriate skills throughout each Learning Unit. The learning experiences found in the Project ProBase curriculum are developed using a four-phase learning cycle.

Phase one: Exploration

During this phase of each learning cycle, students will be exploring selected concepts while engaged in hands-on activities. The explorations are done individually as well as in teams. The goal of the *Exploration* phase is to have students construct accurate knowledge about each concept under investigation.

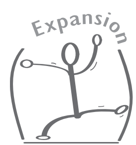
Phase two: Reflection

The *Reflection* phase of the learning cycle offers an opportunity for students to think about what they know about the concepts under investigation. Their reflections are recorded in an Inventor's Logbook that can be used to check their understanding. This phase of the learning cycle also provides an opportunity for the instructor to clear up lingering misconceptions and to be sure that all students are ready to move on.



Phase three: Engagement

The *Engagement* phase of the learning cycle allows the student to apply the knowledge and skills that they are constructing. This phase reinforces their understanding of the important concepts. The activities that students are engaged in are as authentic as possible and are often team activities.



Phase four: Expansion

This phase of the learning cycle is where students can extend their new understandings to new situations. Students should select one of the activities from the several that are suggested. Some of the *Expansion* activities are designed to be done as individuals as homework and some are team activities.

Student and Instructor Roles During Each Phase of the Learning Cycle

Learning Cycle Phase	Student's Role	Instructor's Role
Exploration	• Interacts with materials and equipment • Collects, records, and analyzes data • Designs solutions • Investigates concepts	• Asks questions • Gathers materials • Oversees safety and skills instruction • Encourages Inventor's Logbook entries
Reflection	• Answers questions in Inventor's Logbook • Forms generalizations • Compares team data • Participates in discussions	• Questions students • Leads class discussions • Corrects misconceptions • Facilitates class data sets
Engagement	• Applies concepts, principles, theories • Designs and builds solutions • Solves problems	• Supplies materials • Keeps students on task • Corrects lingering misconceptions • Assures safe practice
Expansion	• Extends concepts to different contexts • Researches • Journals in Inventor's Logbook	• Provides appropriate resources • Questions students to ensure connections are made to broader context

Preparing for the Challenge

A goal of the Project ProBase curriculum is to have students work toward the *Primary Challenge* throughout each Learning Unit. Therefore, at the end of each learning cycle students are asked to reflect on the *Primary Challenge*. In many cases the student is provided time to work on the solution to the *Primary Challenge* for a day or two between learning cycles.

Inventor's Logbook

Each Learning Unit developed by Project ProBase makes use of an Inventor's Logbook. An icon like the one above is placed throughout the Learning Unit whenever students are expected to answer specific questions, record data, or write down their observations. The specific requirements for this logbook are left for you to determine.

The Inventor's Logbook entries will also be used to check and assess student progress toward the concepts that each learning cycle is focused on. The rubrics provided at the end of each learning cycle contain an Inventor's Logbook element where the specific concepts are identified. This will encourage your students to make regular entries in their student text and provide dynamic documentation of their progress.

Student Assessment

Student assessment is an important component in the ProBase curriculum. The Instructor's Guide provides several optional rubrics to use for formative and summative student evaluation. The Inventor's Logbook is designed to be a formative assessment of student progress. The Instructor's Guide contains a rubric for assessing each student's Inventor's Logbook. In addition, each *Primary Challenge* has a rubric for summative evaluation.

The *Engagement* phase of each learning cycle affords a unique opportunity to assess student progress. Therefore, a rubric unique to the *Engagement* phase is provided as often as possible.

Rubrics have been inserted in the Instructor's Guide and Student's Guide for assessing a student's contribution to teamwork and daily engagement/preparation.

Materials and Equipment

The Project ProBase curriculum is designed to be taught in a general technology laboratory facility. Each learning cycle details the equipment and materials needed for that specific activity. Each Learning Unit also includes a compiled list of all the equipment and materials needed for the unit in the front of the Instructor's Guide. By design and as much as possible, the equipment and materials used for the activities are easy to find, over-the-counter materials. Where appropriate and necessary, specific vendors have been identified and their contact information has been provided.

Learning Cycle One:
3a. *What are some of the unforeseen consequences of specific technological changes throughout history?*
3b. *How can a technology cause both good and harm and how do humans prepare for or respond to these impacts?*

Learning Cycle Two:
4b. *What are the key elements of the various technological systems and what are the relationships between these systems?*

Learning Cycle Three:
4a. *What are the systems and subsystems involved in the various contexts of technology?*

Learning Cycle Three:
6a. *To what extent have optimal designs been achieved in the eight technological context areas?*

Learning Cycle One:
9b. *How do technologies communicate with one another and provide information to humans?*

Learning Cycle Two:
9d. *How is technological instrumentation used to measure, calculate, manipulate, and predict the actions of technological devices and systems?*

Learning Cycle Three:
9c. *To what extent are technological systems and devices controlled by people and to what extent are they controlled by other technologies?*

Energy and Power Technologies Overview

Up to this point, we have been discussing the Project ProBase Learning Units in general terms. The following points will be specific to *Energy and Power Technologies*.

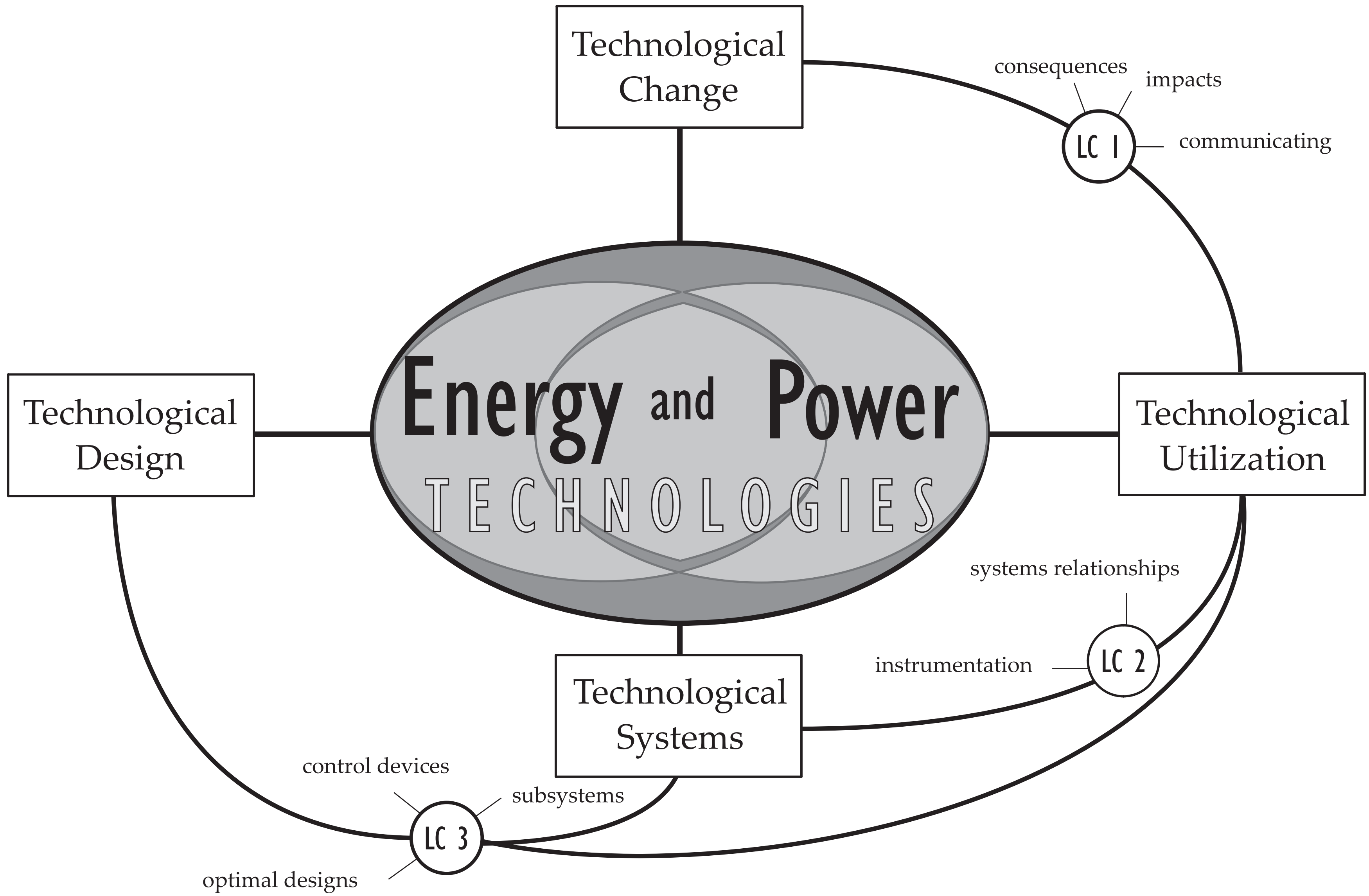
Enduring Understandings and Essential Questions

The *Energy and Power Technologies* Learning Unit focuses on four of the nine enduring understandings. As they complete *Energy and Power Technologies* students will understand:

3. That technological change can be positive and/or negative and can have intended and/or unforeseen social, cultural, environmental, and political consequences.
4. How technological systems work, the components of those systems, and how they fit into the larger technological, economic, and social systems.
6. That the complexities of technological design involve trade-offs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.
9. How to utilize a variety of simple and complex technologies.

The essential questions addressed in each learning cycle will be correlated to the learning cycle objectives.

Energy and Power Technologies Learning Unit Concept Map



Energy and Power Technologies Learning Unit Equipment and Materials List

Learning Unit Consumables (based on a class size of 28 students)

Qty.	Item	Learning Cycle	Notes and Recommended Options
	Solder	*Preliminary*	
1	A simplified Stirling Engine kit	*Preliminary*	Simplified Stirling Engine Kit #1869. Available from Bailey Craftsman Supply (800) 895-5446; www.baileycraft.com.
1	Heavy-wick candle	*Preliminary*	
	Matches	*Preliminary*	
1	Container of water	*Preliminary*	
	Other basic construction materials	*Preliminary*	
1	Plastic 35mm film canister	*Preliminary*	
4	Pennies	*Preliminary*	
4	Lemons	*Preliminary*	
	Vinegar	*Preliminary*	
	Distilled water	*Preliminary*	
	Misc. wood and sandpaper	1	
	String/twine	3	
7	Screws/nails	3	
7	Paper and cardboard stock	3	
	Miscellaneous wood	3	
28	AA batteries	2	
	Miscellaneous plastics	3	
7	One gallon of water and two plastic buckets	3	
	Other items as approved by instructor	3	
	Miscellaneous cardboard and duct tape	3	
	Miscellaneous plastic hose or garden hose	3	
7	Miscellaneous PVC pipe and fittings	3	

Energy and Power Technologies Learning Unit Materials and Equipment List

Learning Unit Equipment (based on a class size of 28 students)

Qty.	Item	Learning Cycle	Notes and Recommended Options
1	3/16″ Thumb screw	*Preliminary*	McMaster part #91745A240
1	Copper Stub Out air chamber	*Preliminary*	
1 pkg	Grease fittings	*Preliminary*	Ace Hardware part #88886
1	Clamping pliers or a small C-Clamp	*Preliminary*	Kelvin part #470094
1	Simple scientific test stand	*Preliminary*	Kelvin part #550129
1	Burette Lincoln Clamp	*Preliminary*	Kelvin part #710198
1	Fishing line	*Preliminary*	Pitsco part #D51817-037
1	1/2″ Copper end cap	*Preliminary*	
1	File	*Preliminary*	
1	Fishing line swivel	*Preliminary*	
1	Propane torch	*Preliminary*	
1	Steel wool	*Preliminary*	
1	Pliers	*Preliminary*	
1	Scissors	*Preliminary*	
1	Various screw-drivers	*Preliminary*	
1	Solar cell 2.0V, 200A	*Preliminary*	Pitsco part #D56852-190
1	Motor mount	*Preliminary*	Pitsco part #D57615-331
7	Electric motors	*Preliminary*, 3	Pitsco part #D54428-331
2	5″– 6″ Plastic propellers	*Preliminary*	Kelvin part #850889
1	#0 Rubber stopper (pkg/63)	*Preliminary*	Kelvin part #710086
	Eye screws with 1/8″ eye hole	*Preliminary*	Pitsco part #D15109-21
1	1″ piece of plastic tubing with an inside diameter less than 1/8″	*Preliminary*	

Learning Unit Equipment cont'd

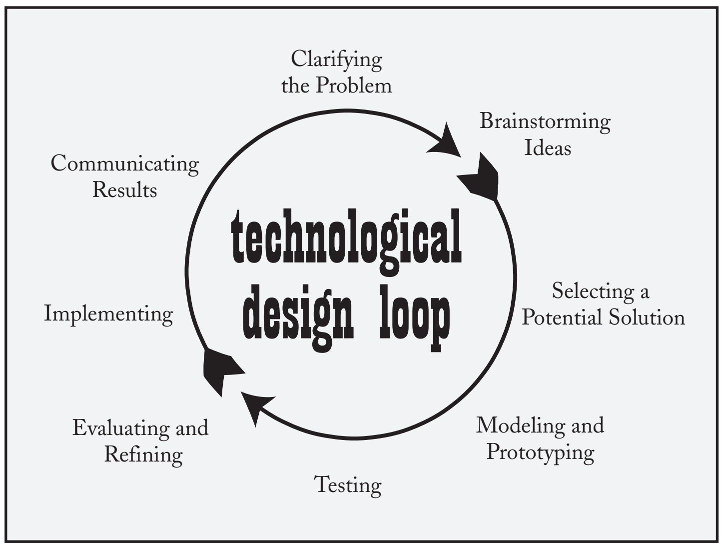
Qty.	Item	Learning Cycle	Notes and Recommended Options
1	Compact disc (CD) (it may be a used disc)	*Preliminary*	
1	Metal rod 1/8" x 5"	*Preliminary*	McMaster part #88565K35
7	Ceramic magnets (4 per pkg)	*Preliminary*, 1	Radio Shack part #64-1877
1	250 ml beaker	*Preliminary*	
7	Multimeters	*Preliminary*	Kelvin part #990177
	14-gauge copper wire	*Preliminary*	
	Aluminum, copper, and zinc strips	*Preliminary*	
4	Galvanized nails	*Preliminary*	
1	Electric or hand-operated drill	*Preliminary*, 1	
7	200 feet of #30 magnet wire	1	Radio Shack part #278-1345
7	16d nails	1	
14	Green LEDs	1,2	Kelvin part #260027
7	Pulleys	3	Kelvin part #841538
7	Bolts/nuts	3	
7	Newton scales and tape measures	3	
	Glue guns and glue	3	
7	Piezo speakers	2	All Electronics #CAT SBZ-413
7	1KΩ resistors	2	All Electronics #1K OHM 1/2 WATT Sku# 1k-1/2
14	Red LEDs	2	Kelvin part #260020
7	Breadboards	2	Kelvin part #680093
1 pkg	Jumper wires	2	Kevlin part #330289
7	(2) AA battery holders	2	Kelvin Part #220090

Learning Unit Equipment cont'd

Qty.	Item	Learning Cycle	Notes and Recommended Options
14	Alligator clips	Prelim. Prim.,2,3	Kelvin part #330009
7	10KΩ resistors	2	All Electronics 10K OHM 1/2 WATT Sku# 10k-1/2
7	100kΩ resistors	2	All Electronics 100K OHM 1/2 WATT Sku# 100k-1/2
7	10μF capacitors	2	All Electronics 10MFD/16V RADIAL ELECTROLYTIC CAPACITOR Sku # 10/16VR
7	3.3KΩ resistors	2	All Electronics 3.3K OHM 1/2 WATT Sku# 3.3k-1/2
7	100μF capacitors	2	All Electronics 100MFD/16V RADIAL Sku # 10/16VR
7	Diode s	2	All Electronics #1N4148
7	470KΩ resistors	2	All Electronics 470K OHM 1/2 WATT Sku# 470k-1/2
7	NPN transistors	2	All Electronics #2N4400
7	1MΩ resistors	2	All Electronics 1M OHM 1/2 WATT Sku# 1M-1/2
7	Transformers	2	All Electronics #TX-4025
7	(4) AA battery holders	2	Kelvin part #220004
7	Button switchs	2	Kelvin part #990074
7	0.0047 μF capacitors	2	All Electronics #472D50
7	Bicyle generator/ Lights	3	Ace Hardware part #8005217
7	Wooden boat hulls	3	
7	Plastic chains and sprockets	3	Kelvin part #750189
7	Stop watches	3	

THE ProBase DESIGN MODEL

As a constructivist, problem-based curriculum, the ProBase Learning Units offer a variety of opportunities for students to engage in design activities. The ProBase Learning Units have been developed for upper high school technology education students. It is assumed that students engaging in the ProBase curriculum possess some prerequisite knowledge and skills regarding engineering design. If students do not have previous experience in this area, it may be necessary to provide a brief introduction to design-based problem solving. It is suggested that you use the following design model adapted for the ProBase curriculum from *Standards for Technological Literacy* (International Technology Education Association, 2000/2002).



If you see a need to introduce the design-based problem solving process, it is suggested that you do so in a constructivist manner using a simple design problem. For example, you might have your students use the model presented above as they design a cover for a book or CD. You should attempt to use media beyond paper and pencil such as modeling clay, Styrofoam™, Balsa wood, or cardboard. Other simple design ideas include designing paper airplanes, a package for their favorite snack, a marketing flyer for a new product, an ergonomic handle for a shaving razor, or prototype cardboard seat or a model of other furniture pieces.

Energy and Power Technologies Unit Calendar

Week	Day 1	Day 2	Day 3	Day 4	Day 5
1	Course Introduction; Preliminary Challenge	Preliminary Challenge	Preliminary Challenge	Preliminary Challenge	Intro to Primary Challenge; Enduring Understandings
2	Learning Cycle 1 - *Exploration*	Learning Cycle 1 - *Exploration*	Learning Cycle 1 - *Reflection*	Learning Cycle 1 - *Engagement*	Learning Cycle 1 - *Engagement*
3	Learning Cycle 1 - *Engagement*	Learning Cycle 1 - *Engagement*	Preparing for the Challenge	Learning Cycle 2 - *Exploration*	Learning Cycle 2 - *Exploration*
4	Learning Cycle 2 - *Exploration*	Learning Cycle 2 - *Exploration*	Learning Cycle 2 - *Exploration*	Learning Cycle 2 - *Exploration*	Learning Cycle 2 - *Exploration*
5	Learning Cycle 2 - *Reflection*	Learning Cycle 2 - *Engagement*	Learning Cycle 2 - *Engagement*	Preparing for the Challenge	Learning Cycle 3 - *Exploration*
6	Learning Cycle 3 - *Exploration*	Learning Cycle 3 - *Exploration*	Learning Cycle 3 - *Exploration*	Learning Cycle 3 - *Exploration*	Learning Cycle 3 - *Exploration* *Reflection*
7	Learning Cycle 3 - *Engagement*	Learning Cycle 3 - *Engagement*	Learning Cycle 3 - *Engagement*	Learning Cycle 3 - *Engagement*	Preparing for the Primary Challenge
8	Primary Challenge	Primary Challenge	Primary Challenge	Primary Challenge	Primary Challenge
9	Primary Challenge	Primary Challenge	Primary Challenge	Presentations of the Primary Challenge	Presentations of the Primary Challenge

* For block scheduling, adjust the Unit Calendar appropriately

Energy and Power Technologies

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Preliminary

Preliminary and Primary Challenges

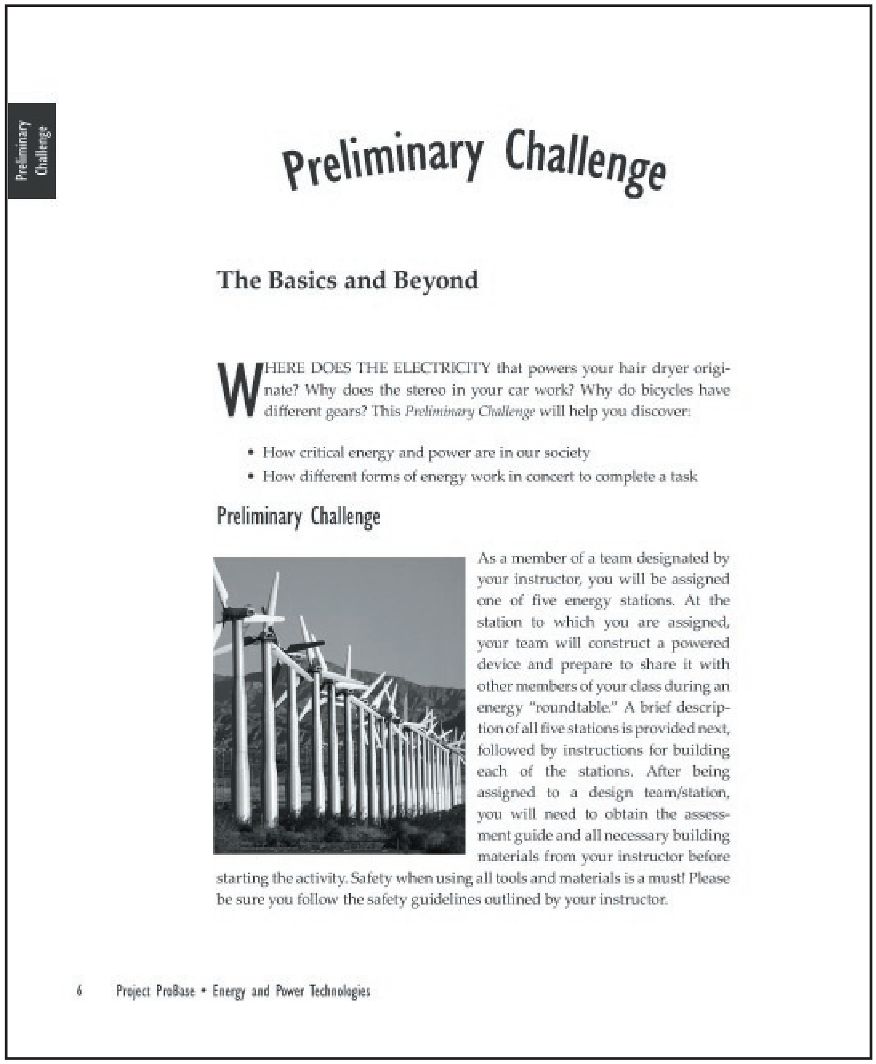
Primary

The Basics and Beyond

Introduction

Through this *Preliminary Challenge,* students will be building and experimenting with different energy and power systems. This *Preliminary Challenge* is a team-based activity. After reading the material below, you will need to place all students into teams and assign each team a problem to complete. The activities are structured in such a way that each team of students will follow a set of directions to complete one of the activities. They will then be expected to present their device to the other teams in the class.

The activities in this *Preliminary Challenge* were designed to be an introductory experience for the students; thus, the activities will not provide the students with an in-depth background on all of the respective experiments and technologies. It is important to assign students to teams while considering the varying levels of cognitive and kinesthetic abilities for each student/team. These activities should be completed in four class periods or less.



Preliminary Challenge

Preliminary Challenge

The Basics and Beyond

WHERE DOES THE ELECTRICITY that powers your hair dryer originate? Why does the stereo in your car work? Why do bicycles have different gears? This *Preliminary Challenge* will help you discover:

- How critical energy and power are in our society
- How different forms of energy work in concert to complete a task

Preliminary Challenge

As a member of a team designated by your instructor, you will be assigned one of five energy stations. At the station to which you are assigned, your team will construct a powered device and prepare to share it with other members of your class during an energy "roundtable." A brief description of all five stations is provided next, followed by instructions for building each of the stations. After being assigned to a design team/station, you will need to obtain the assessment guide and all necessary building materials from your instructor before starting the activity. Safety when using all tools and materials is a must! Please be sure you follow the safety guidelines outlined by your instructor.

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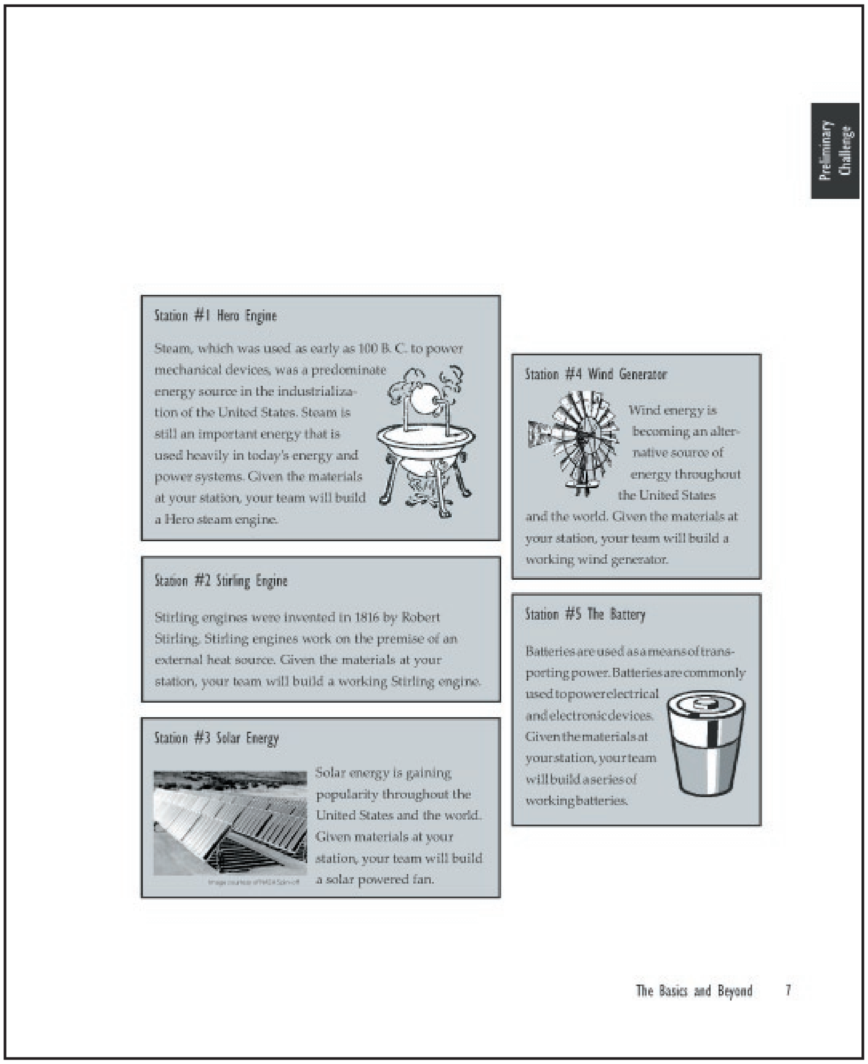
Note: Student teams will be assigned to one activity/energy station. In the event that you have a large class, you may need to assign the same station to multiple teams and have them create different designs. After all teams have completed their designs, the teams should take turns presenting a demonstration to the remainder of students in the class (the other teams).



Preliminary Challenge

Station #1 Hero Engine

Steam, which was used as early as 100 B. C. to power mechanical devices, was a predominate energy source in the industrialization of the United States. Steam is still an important energy that is used heavily in today's energy and power systems. Given the materials at your station, your team will build a Hero steam engine.

Station #2 Stirling Engine

Stirling engines were invented in 1816 by Robert Stirling. Stirling engines work on the premise of an external heat source. Given the materials at your station, your team will build a working Stirling engine.

Station #3 Solar Energy

Solar energy is gaining popularity throughout the United States and the world. Given materials at your station, your team will build a solar powered fan.

Station #4 Wind Generator

Wind energy is becoming an alternative source of energy throughout the United States and the world. Given the materials at your station, your team will build a working wind generator.

Station #5 The Battery

Batteries are used as a means of transporting power. Batteries are commonly used to power electrical and electronic devices. Given the materials at your station, your team will build a series of working batteries.

The Basics and Beyond 7

Key Concepts

Each Learning Unit is designed to facilitate several enduring understandings. The key concepts have been synthesized from the enduring understandings and essential questions and will focus the learning cycles in this Learning Unit. Each learning cycle is keyed to one or more of the following enduring understandings:

Students will understand:

2. that **technological** development for the solution of a problem in one context can **spin-off** for use in a variety of often unrelated applications.
3. that **technological change** can be positive and/or negative and can have intended and/or unforeseen social, cultural, environmental, and political consequences.
4. how **technological systems** work, the components of those systems, and how they fit into the larger technological, economic, and social systems.
9. how to **utilize** a variety of simple and complex **technologies**.

Learning Unit Goal

The Learning Unit goal provides a target for the Energy and Power Learning Unit. As students complete this unit, they will be able to:

Demonstrate how various forms of energy are used to create power and understand how various power systems operate and risks and benefits of each.

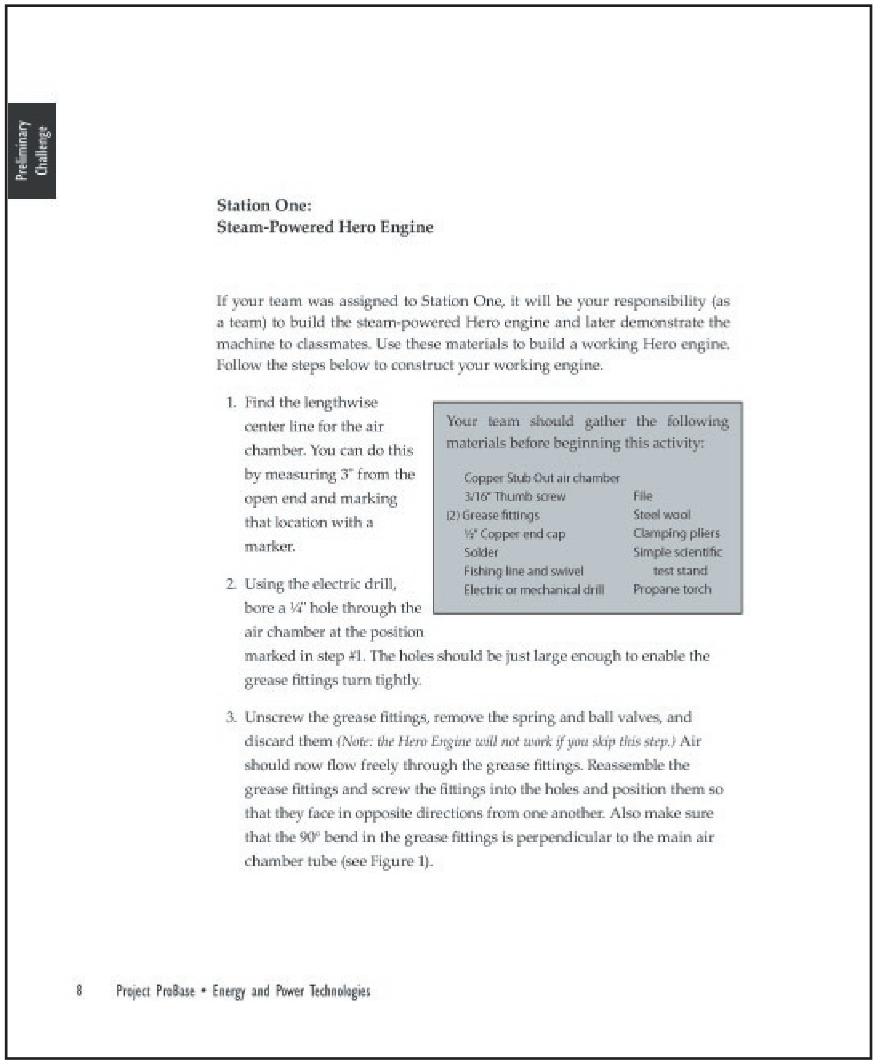
Facility Requirements

There are no special arrangements needed for these activities.

Suggested Daily Outline

Day	Activities
Day One	Introduction, Stations
Day Two	Stations
Day Three	Stations, Presentations
Day Four	Presentations, *Reflection*
Day Five	Intro to Primary Challenge

Estimated Number of 50-minute class periods: **5**


Preliminary Challenge

Station One:
Steam-Powered Hero Engine

If your team was assigned to Station One, it will be your responsibility (as a team) to build the steam-powered Hero engine and later demonstrate the machine to classmates. Use these materials to build a working Hero engine. Follow the steps below to construct your working engine.

Your team should gather the following materials before beginning this activity:

Copper Stub Out air chamber	File
3/16" Thumb screw	Steel wool
(2) Grease fittings	Clamping pliers
½" Copper end cap	Simple scientific test stand
Solder	Propane torch
Fishing line and swivel	
Electric or mechanical drill	

1. Find the lengthwise center line for the air chamber. You can do this by measuring 3" from the open end and marking that location with a marker.
2. Using the electric drill, bore a ¼" hole through the air chamber at the position marked in step #1. The holes should be just large enough to enable the grease fittings turn tightly.
3. Unscrew the grease fittings, remove the spring and ball valves, and discard them *(Note: the Hero Engine will not work if you skip this step.)* Air should now flow freely through the grease fittings. Reassemble the grease fittings and screw the fittings into the holes and position them so that they face in opposite directions from one another. Also make sure that the 90° bend in the grease fittings is perpendicular to the main air chamber tube (see Figure 1).

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While the students are working on their activities, ask them what they are learning, why it is important, and how the activities relate to their world.

Students should create a poster or another appropriate presentation of their energy source for use during an energy roundtable. The energy roundtable is meant to be a brief session where each team is allowed three to five minutes to present and discuss its energy devices and the things that the students learned while building the devices. Encourage students to point out the possible benefits and risks for their devices during this roundtable.

Teaching Tips

Divide the students into the teams you feel are most appropriate. If you feel safety rules and/or demonstrations should take place, please do so at this time. Explain to the class what will occur in the next couple of class periods during the *Preliminary Challenge.*

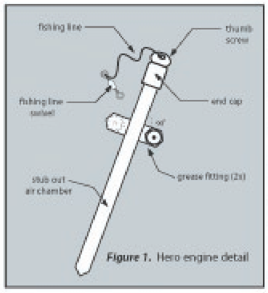

Figure 1. Hero engine detail

4. Drill a $\frac{3}{16}$" hole in the center of the ½" copper end cap and remove any burrs with a file or steel wool (check with your instructor).

5. After thoroughly cleaning both the inside of the end cap and the end of the air chamber with steel wool, coat both pieces with solder flux and place the end cap on the air chamber.

6. After notifying your instructor, use the torch to heat the end cap and solder it to the air chamber. Take extreme caution with all parts, as they will be very hot!

7. Using a C-clamp or other holding device and an electric drill, drill a small hole (⅛") through the flat part of the thumb screw for attaching the fishing line and swivel. *(Note: the swivel will allow the engine to rotate.)* Remove any burrs with a metal file or other approved tool and twist the thumb screw into the end cap and attach the fishing line and swivel.

8. Mount the completed Hero engine to the scientific test stand or other permanent structure so that it hangs from the fishing line in a horizontal fashion.

Safety

Whenever using a torch, be sure that the area is clean and free of combustible materials. Make certain that team members and other classmates are at a safe distance before heating the engine; the steam will be very hot and hot water could potentially spew from the grease fitting. Take care not to get too close to the spinning engine. The engine should never be heated without an instructor present.

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Encourage your students to take notes about each device during the presentations. If your room is large enough, you may be able to have several presentations going on at different tables simultaneously and rotate each team through each station.

After the *Preliminary Challenge* you may want to keep the energy and power devices on display in your classroom and encourage students to experiment with the devices during free time. This will likely build curiosity among students.

Equipment and Materials

Per team based on a class of 28 students

Station One:
Hero Engine

½″ x 8″ Stub Out Air Chamber

3/16″ 1 thumb screw

½″ Copper end cap

(2) 90° grease fittings

Fishing line swivel

4-6 lb. test fishing line

Solder

Propane torch

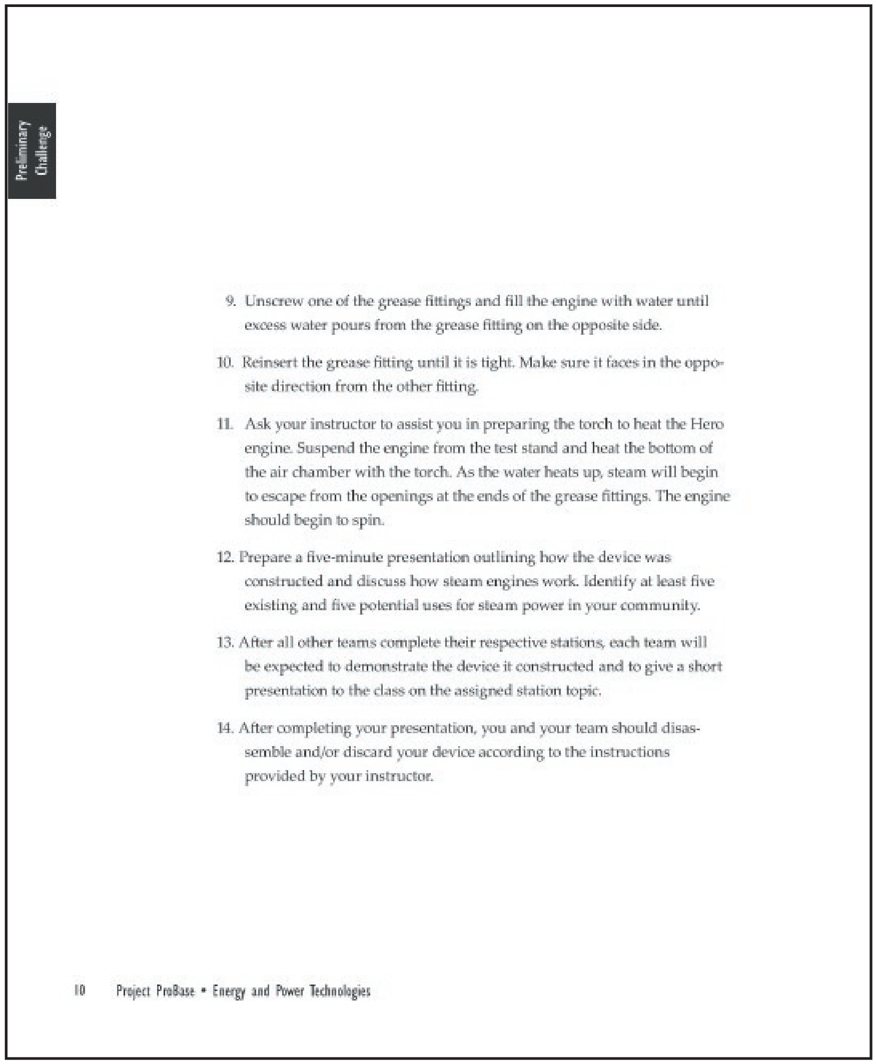
Drill

File

Steel Wool

Clamping pliers

Simple scientific test stand



Preliminary Challenge

9. Unscrew one of the grease fittings and fill the engine with water until excess water pours from the grease fitting on the opposite side.
10. Reinsert the grease fitting until it is tight. Make sure it faces in the opposite direction from the other fitting.
11. Ask your instructor to assist you in preparing the torch to heat the Hero engine. Suspend the engine from the test stand and heat the bottom of the air chamber with the torch. As the water heats up, steam will begin to escape from the openings at the ends of the grease fittings. The engine should begin to spin.
12. Prepare a five-minute presentation outlining how the device was constructed and discuss how steam engines work. Identify at least five existing and five potential uses for steam power in your community.
13. After all other teams complete their respective stations, each team will be expected to demonstrate the device it constructed and to give a short presentation to the class on the assigned station topic.
14. After completing your presentation, you and your team should disassemble and/or discard your device according to the instructions provided by your instructor.

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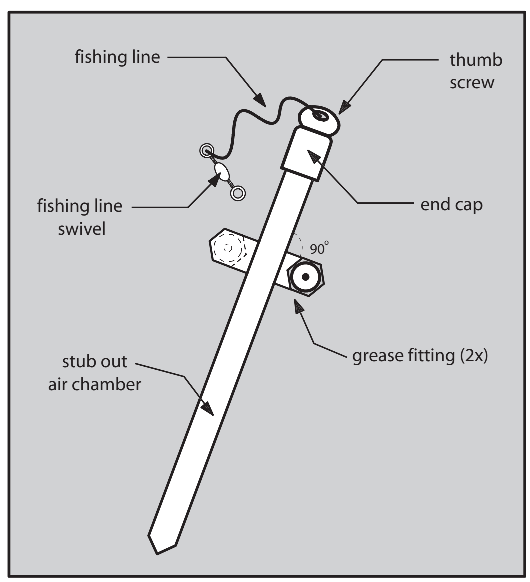
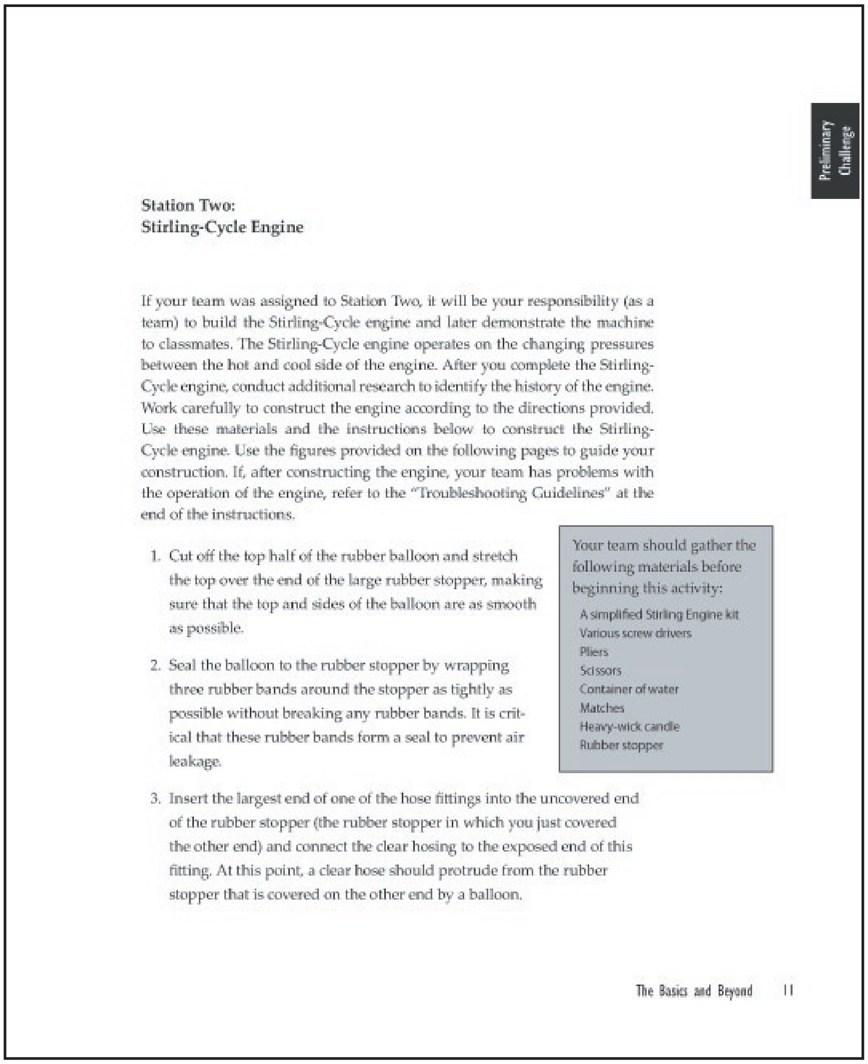


Figure 1. Hero Engine detail



**Station Two:
Stirling-Cycle Engine**

If your team was assigned to Station Two, it will be your responsibility (as a team) to build the Stirling-Cycle engine and later demonstrate the machine to classmates. The Stirling-Cycle engine operates on the changing pressures between the hot and cool side of the engine. After you complete the Stirling-Cycle engine, conduct additional research to identify the history of the engine. Work carefully to construct the engine according to the directions provided. Use these materials and the instructions below to construct the Stirling-Cycle engine. Use the figures provided on the following pages to guide your construction. If, after constructing the engine, your team has problems with the operation of the engine, refer to the "Troubleshooting Guidelines" at the end of the instructions.

Your team should gather the following materials before beginning this activity:

- A simplified Stirling Engine kit
- Various screw drivers
- Pliers
- Scissors
- Container of water
- Matches
- Heavy-wick candle
- Rubber stopper

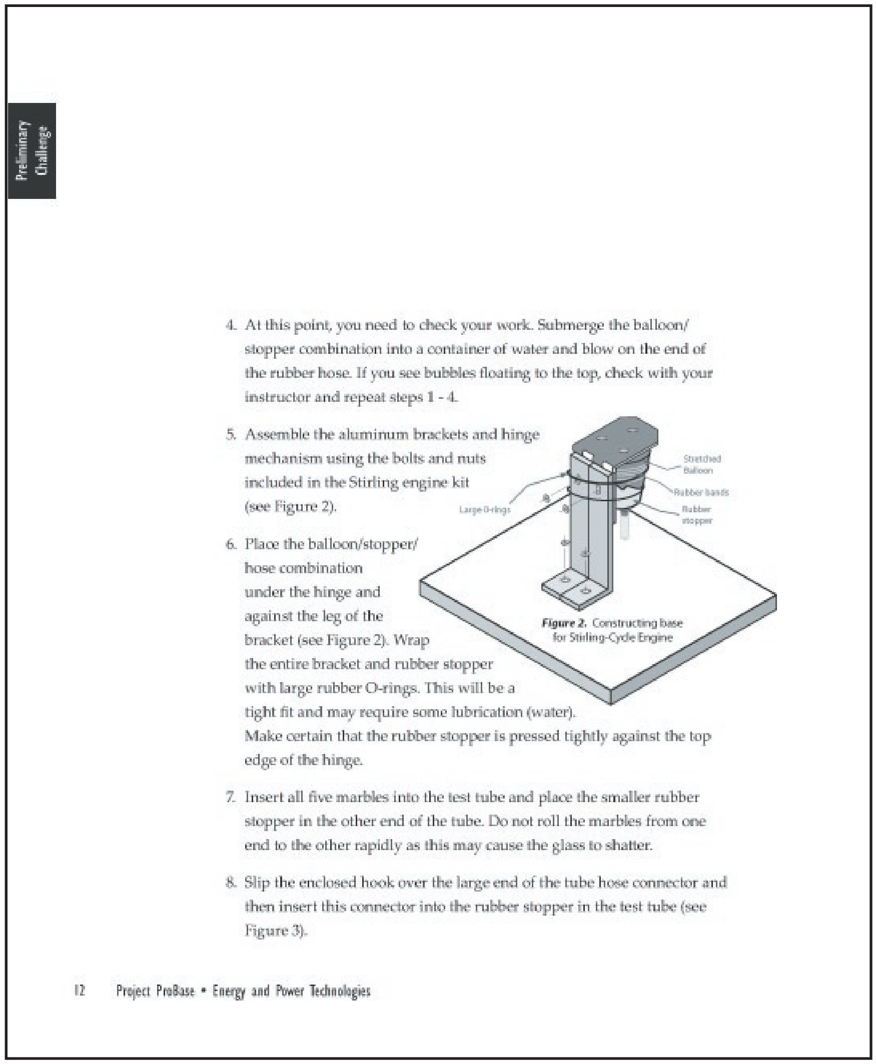
1. Cut off the top half of the rubber balloon and stretch the top over the end of the large rubber stopper, making sure that the top and sides of the balloon are as smooth as possible.
2. Seal the balloon to the rubber stopper by wrapping three rubber bands around the stopper as tightly as possible without breaking any rubber bands. It is critical that these rubber bands form a seal to prevent air leakage.
3. Insert the largest end of one of the hose fittings into the uncovered end of the rubber stopper (the rubber stopper in which you just covered the other end) and connect the clear hosing to the exposed end of this fitting. At this point, a clear hose should protrude from the rubber stopper that is covered on the other end by a balloon.

Teaching Tips

While students are working at their stations, walk around the classroom and ask the students what they are learning and why this form of energy is important.

Station Two: Stirling Engine

Simplified Stirling Engine Kit #1869. Available from Bailey Craftsman Supply (800) 895-5446; www.baileycraft.com
An illustration and directions will come with the kit from Bailey Craftsman Supply.



4. At this point, you need to check your work. Submerge the balloon/stopper combination into a container of water and blow on the end of the rubber hose. If you see bubbles floating to the top, check with your instructor and repeat steps 1 - 4.

5. Assemble the aluminum brackets and hinge mechanism using the bolts and nuts included in the Stirling engine kit (see Figure 2).

Figure 2. Constructing base for Stirling-Cycle Engine

6. Place the balloon/stopper/hose combination under the hinge and against the leg of the bracket (see Figure 2). Wrap the entire bracket and rubber stopper with large rubber O-rings. This will be a tight fit and may require some lubrication (water). Make certain that the rubber stopper is pressed tightly against the top edge of the hinge.

7. Insert all five marbles into the test tube and place the smaller rubber stopper in the other end of the tube. Do not roll the marbles from one end to the other rapidly as this may cause the glass to shatter.

8. Slip the enclosed hook over the large end of the tube hose connector and then insert this connector into the rubber stopper in the test tube (see Figure 3).

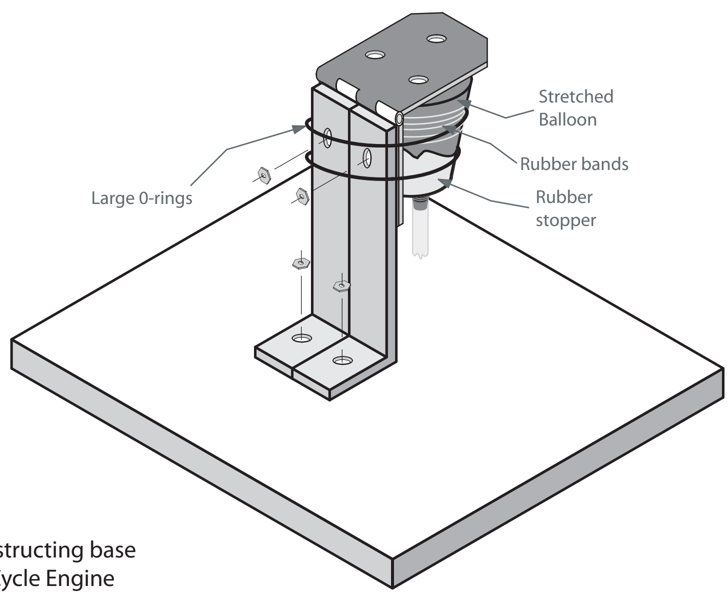


Figure 2. Constructing base for Stirling-Cycle Engine

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9. Push the unattached end of the rubber hose onto the small end of the hose connector.

10. Rest the test tube on top of the hinge and slide on the two smaller O-rings. Carefully, place the flat piece of metal between the balloon and hinge. Adjust the test tube back and forth until the marbles (when placed into the sealed end of the test tube) just slowly roll toward the other (stopper) end when the tube is released in a horizontal manner (see Figure 3). In other words, the balance should be slightly in favor of the stopper end of the test tube.

11. Momentarily, unhook the rubber tube from the end of the test tube and blow air into the hose until the test tube reaches a horizontal resting position. Pinch off the hose and reinsert it onto the tube *(Note: This procedure may have to be repeated several times to achieve a horizontal position.)*

12. Ask your instructor to check your work and then test the Stirling-Cycle engine.

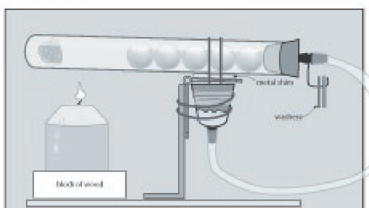

Figure 3. The completed Stirling-Cycle Engine

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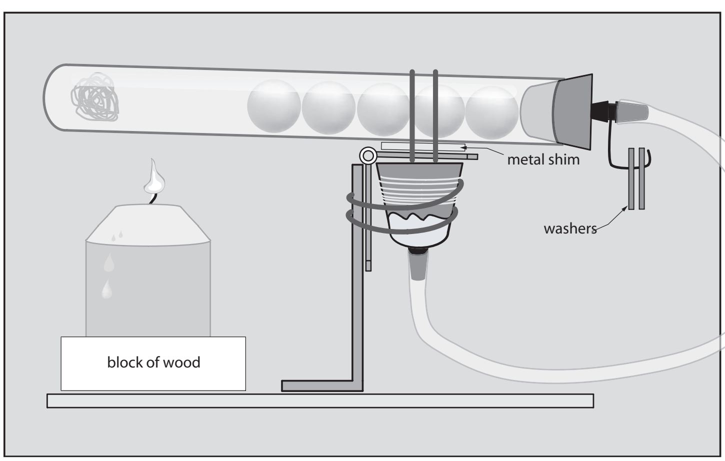

Figure 3. The completed Stirling-Cycle Engine

Notes:

Teaching Tips

Ask students what is causing the tube to move up and down. Have the students give examples of where this type of energy is used.

13. With your instructor's permission, place a heavy-wicked candle (the candle that comes with the kit may need to be replaced with a more heavily wicked candle) under the sealed end of the test tube and wait. It is very important to block all sources of wind or moving air from the candle. If the candle flame does not continuously strike the test tube in one spot, it may never reach a sufficient temperature.
14. The heat inside the tube should be transferred through the rubber hose to the balloon. As the balloon expands, the test tube should start to tilt and marbles should start to roll toward the opposite end of the chamber. As the marbles roll to the other end, the pressure should change and cause the tube to rock back again.
15. In the case that the engine fails to rock one way or the other, washers may be added to the hook to balance the engine. Once the weights are added and the pressure is sufficient, the engine should operate smoothly.
16. Prepare a five-minute presentation outlining how the device was constructed and how Stirling engines work. Identify at least five existing and five potential uses for the Stirling-Cycle engine in your community.
17. After all other teams complete their respective stations, each team will be expected to demonstrate the device it constructed and give a short presentation to the class on the assigned station topic.
18. After completing your presentation, your team should disassemble and/or discard the device according to the instructions provided by your instructor.

Preliminary Challenge

Troubleshooting Guide

If the engine does not start to move:

1. Review the directions and illustration to ensure that the engine is constructed correctly.
2. Check the amount of air in the balloon. Too much air will cause the test tube to lean forward and will prevent it from tilting back to the stopper end. Too little air will prevent the test tube from titling forward.
3. Check to see if the piece of metal is between the hinge and the balloon.
4. Check to see that the tube is balanced properly.

If the engine does not run for very long:

1. Add more washers. The required weight needed to keep the engine running may change with the amount of heat. Add washers one at a time as needed.
2. Giving the engine a small push will sometimes start the engine.
3. Placing a piece of ice on the rubber hose will increase the deferential between hot and cold and the engine may run more smoothly.
4. If the engine leans forward once and does not lean back, there may be too much air in the balloon.

Notes:

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Station Three: Solar Fan

Solar panel, 200 mA with 2V output. (These are available through a number of vendors such as Pitsco # D56852-190.)

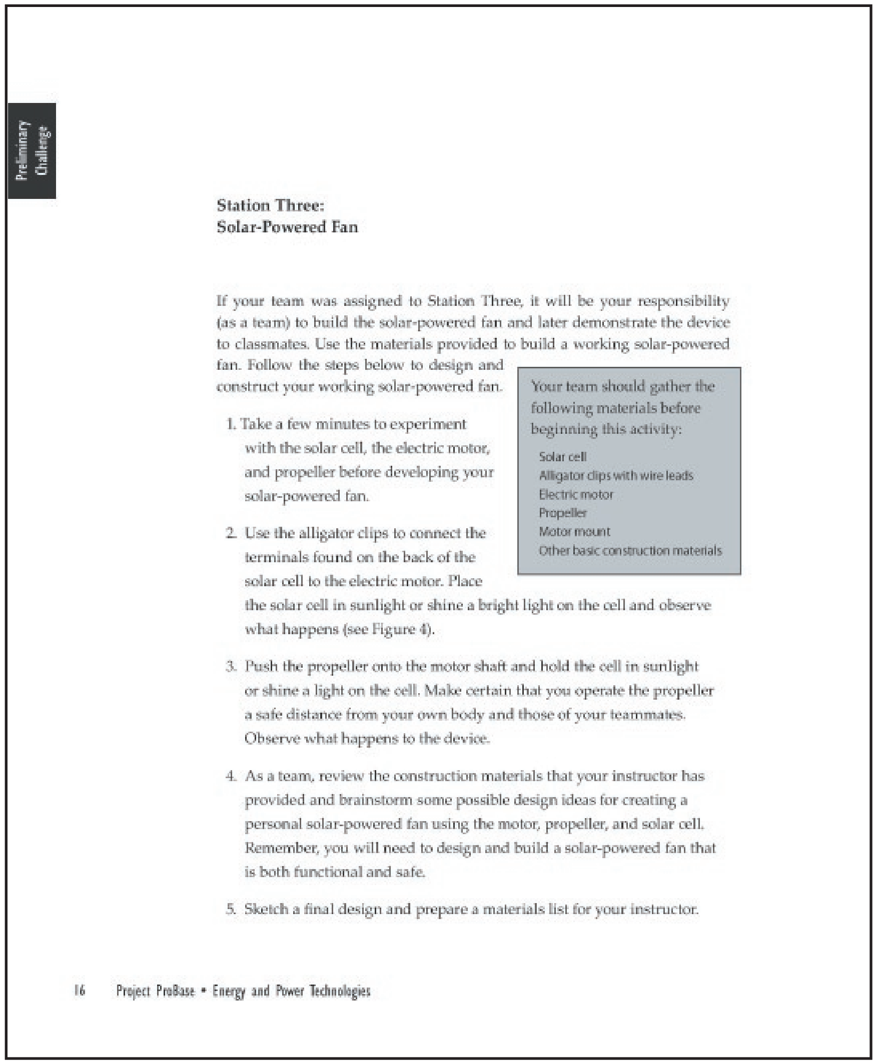
Plastic 5″ – 6″ propeller

Motor 1V to 1.5 V. These are available through a number of vendors such as Kelvin, Part #851254.

Motor Mount 11/16″ I.D.

(2) Alligator clips with leads

Various construction/ modeling materials such as cardboard, foam core, etc. to design and construct the solar fan mounting device.



Preliminary Challenge

Station Three: Solar-Powered Fan

If your team was assigned to Station Three, it will be your responsibility (as a team) to build the solar-powered fan and later demonstrate the device to classmates. Use the materials provided to build a working solar-powered fan. Follow the steps below to design and construct your working solar-powered fan.

Your team should gather the following materials before beginning this activity:

- Solar cell
- Alligator clips with wire leads
- Electric motor
- Propeller
- Motor mount
- Other basic construction materials

1. Take a few minutes to experiment with the solar cell, the electric motor, and propeller before developing your solar-powered fan.
2. Use the alligator clips to connect the terminals found on the back of the solar cell to the electric motor. Place the solar cell in sunlight or shine a bright light on the cell and observe what happens (see Figure 4).
3. Push the propeller onto the motor shaft and hold the cell in sunlight or shine a light on the cell. Make certain that you operate the propeller a safe distance from your own body and those of your teammates. Observe what happens to the device.
4. As a team, review the construction materials that your instructor has provided and brainstorm some possible design ideas for creating a personal solar-powered fan using the motor, propeller, and solar cell. Remember, you will need to design and build a solar-powered fan that is both functional and safe.
5. Sketch a final design and prepare a materials list for your instructor.

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6. Construct the fan according to your team's design, making certain that the completed fan includes:
   - A design that completely encloses the propeller.
   - A design that can be switched off and on easily.
   - A design that will allow the fan to be rotated in any direction while maintaining electric current from the solar cell.
7. When the design is completed and has been tested, prepare a five-minute presentation outlining how the device was constructed, how solar power works, and identify at least five existing and five potential uses for solar power in your community.
8. After all other teams complete their respective stations, each team will be expected to demonstrate the device it constructed and give a short presentation to the class on the assigned station topic.
9. After completing your presentation, your team should disassemble and/or discard the device according to the instructions provided by your instructor.

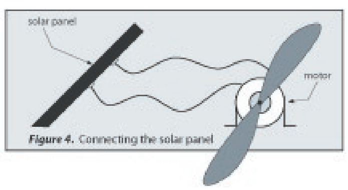

Figure 4. Connecting the solar panel

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Teaching Tips

Ask the students to describe to you the trade-offs of using solar energy to power different devices.

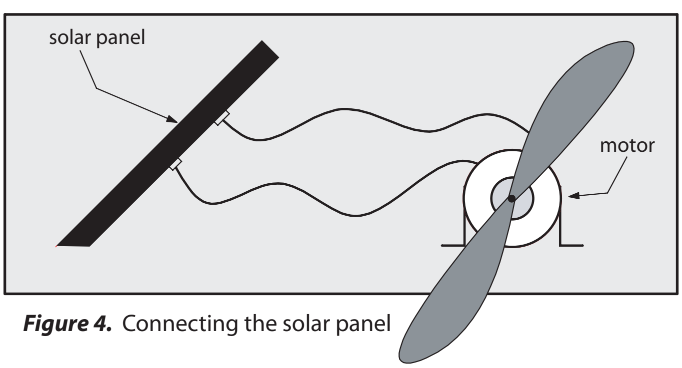


Figure 4. Connecting the solar panel

Preliminary Challenge

Station Four: Wind Generator

Plastic 5″ – 6″ Propeller

Compact disc (may be a used disc)

Metal rod; ⅛″ x 5″

Rubber stopper #0

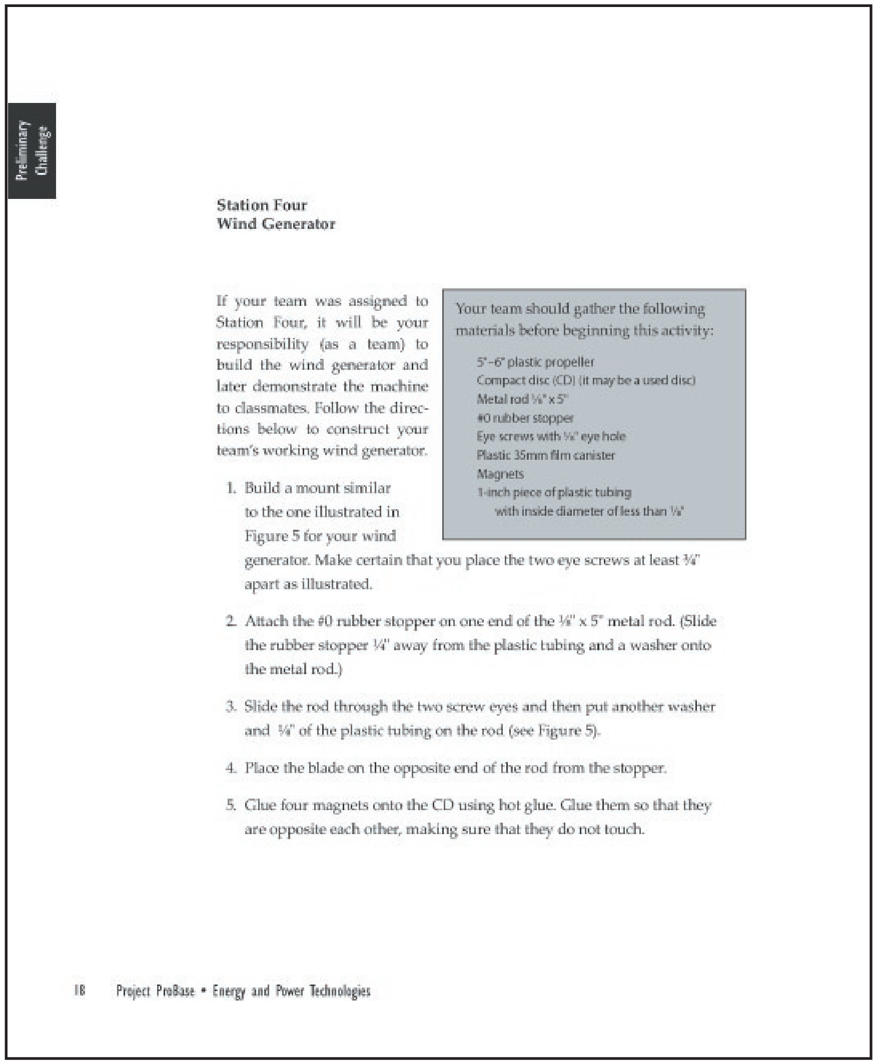
(2) Eye screws with ⅛" eye hole

Plastic 35mm film canister

(8) Magnets: size and shape can vary from the diagram as long as all magnets are the same

1″ plastic tubing with an inside diameter of less than ⅛″

Various pieces of wood to construct a stand for the wind generator according to student designs



Preliminary Challenge

Station Four
Wind Generator

If your team was assigned to Station Four, it will be your responsibility (as a team) to build the wind generator and later demonstrate the machine to classmates. Follow the directions below to construct your team's working wind generator.

Your team should gather the following materials before beginning this activity:

- 5"–6" plastic propeller
- Compact disc (CD) (it may be a used disc)
- Metal rod ⅛" x 5"
- #0 rubber stopper
- Eye screws with ⅛" eye hole
- Plastic 35mm film canister
- Magnets
- 1-inch piece of plastic tubing with inside diameter of less than ⅛"

1. Build a mount similar to the one illustrated in Figure 5 for your wind generator. Make certain that you place the two eye screws at least ¾" apart as illustrated.
2. Attach the #0 rubber stopper on one end of the ⅛" x 5" metal rod. (Slide the rubber stopper ¼" away from the plastic tubing and a washer onto the metal rod.)
3. Slide the rod through the two screw eyes and then put another washer and ¼" of the plastic tubing on the rod (see Figure 5).
4. Place the blade on the opposite end of the rod from the stopper.
5. Glue four magnets onto the CD using hot glue. Glue them so that they are opposite each other, making sure that they do not touch.

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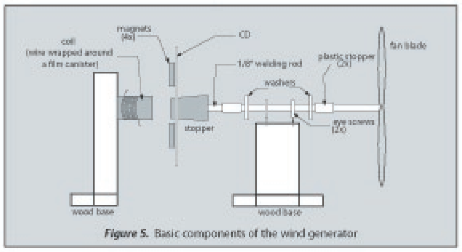

Figure 5. Basic components of the wind generator

6. Place the CD on the stopper, making certain that the magnets face outward. Balance the generator by adjusting the plastic tubing to achieve maximum balance in the generator.

7. Build a mount similar to the one illustrated in Figure 5 for the coil. This mount will hold the coil side of the generator. Make the coil mount 2½" taller than the generator mount. You also need to make certain that the mount allows for the coils to be removed during the experiment outlined in Step #10 on the following page.

8. Make three different coils. Measure out three lengths of wire. One length of wire should be 20 feet, the second should be 30 feet, and the third should be 40 feet long. Wrap coils of copper wire around three different plastic 35mm film canisters as neatly as possible. One coil should contain 20 feet of copper wire, one should contain 30 feet, and one should contain 40 feet of wire. Leave at least two inches of copper wire extending from each end of each coil. Use sandpaper to remove the enamel from the ends of the copper wire on each of the coils.

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Teaching tips

Ask the students what wind generators are used for in our society. Airplanes, computer fans, and household fans are a few examples.

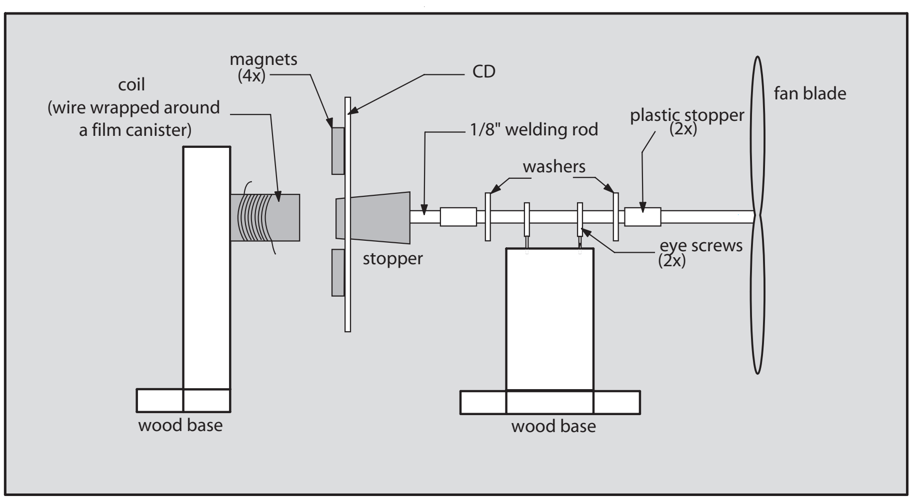

Figure 5. Basic components of the wind generator

Preliminary Challenge

9. Place the coil mount next to the CD, making sure that when the CD is rotated, the magnets travel across the path of the coil but do not actually touch the coil (see Figure 5). Note: It is important that the coil and the magnets pass very closely as the device is rotated.

10. You are now going to conduct experiments with the three different coils to determine which is the most efficient.

    - Place the smallest coil (20 wraps of copper wire) on the mount and place the generator in front of a fan. Attach a millivoltmeter or multimeter on both sides of the coil and record how much current is produced.
    - Place the middle sized coil (30 wraps of copper wire) on the device and record how much current is produced.
    - Place the largest coil (40 wraps of copper wire) on the device and record how much current is produced.

11. Prepare a five-minute presentation outlining how the device was constructed and describe how wind generators work Identify at least five existing and five potential uses for wind generators in your community.

12. After all other teams complete their respective stations, each team will be expected to demonstrate the device it constructed and give a short presentation to the class on the assigned station topic.

13. After completing your presentation, you and your team should disassemble and/or discard your device according to the instructions provided by your instructor.

Notes:


Preliminary Challenge

Station Five:
Battery Model

If your team was assigned to Station Five, it will be your responsibility (as a team) to build a variety of batteries and later demonstrate the batteries to your classmates. At first glance, these batteries may seem elementary in nature; however, your team will undoubtedly need the knowledge and skills learned in this station for the *Primary Challenge*.

During this activity, you will be constructing three different batteries. Before you begin constructing the batteries you will need to develop a matrix or graph to record the voltage and milliamps and any other experimental information for all three batteries.

Batteries contain chemicals that cause a chemical reaction which generates electricity. The chemicals are called electrolytes because they allow electricity to flow through them. An electric current is actually a flow of electrons. All batteries have a positive (+) and a negative (-) electrode. Electrons will flow from the "-" electrode to the "+" electrode of a battery. Voltage is a measure of the movement of electrons. Certain materials, called conductors, allow electrons to flow through them. Most metals (aluminum, copper, iron) are good conductors of electricity.

Your team should gather the following materials before beginning this activity:

(4) Galvanized nails
(4) Copper pennies
(4) Lemons
14-gauge copper wire
Aluminum strip
Copper strip
Zinc strip
Steel wool
250-mL beaker
0.1 M hydrochloric acid (HCl)
Vinegar
Distilled water
(7) Alligator clips
Multimeter

Building a lemon battery

Follow the directions given to construct your team's first battery:

1. Cut a slit in one side of the lemon and insert a copper penny.

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Station Five: Battery Models

(4) Lemons

(4) Pennies

(4) Galvanized nails

(5) Sets of alligator clips

Multimeter with connecting wires

14-gauge copper wire

(4) Low-voltage LEDs (light emitting diode)

Aluminum strip

Copper strip

Zinc strip

Steel wool

250-ml beaker

Vinegar

Distilled water

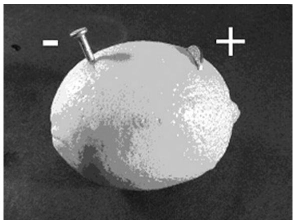


Figure 6.

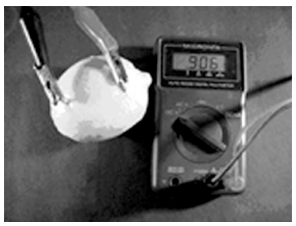


Figure 7.

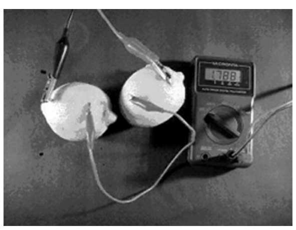
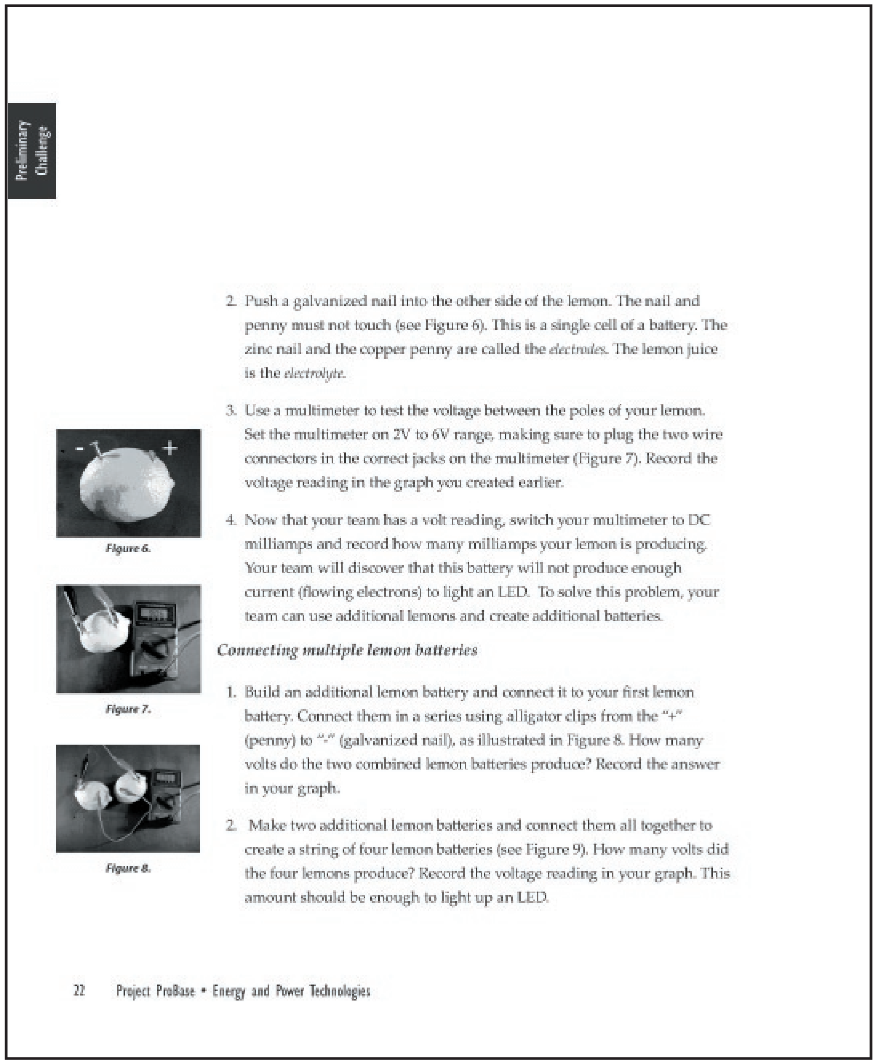


Figure 8.



Preliminary Challenge

2. Push a galvanized nail into the other side of the lemon. The nail and penny must not touch (see Figure 6). This is a single cell of a battery. The zinc nail and the copper penny are called the *electrodes*. The lemon juice is the *electrolyte*.

3. Use a multimeter to test the voltage between the poles of your lemon. Set the multimeter on 2V to 6V range, making sure to plug the two wire connectors in the correct jacks on the multimeter (Figure 7). Record the voltage reading in the graph you created earlier.

4. Now that your team has a volt reading, switch your multimeter to DC milliamps and record how many milliamps your lemon is producing. Your team will discover that this battery will not produce enough current (flowing electrons) to light an LED. To solve this problem, your team can use additional lemons and create additional batteries.

Figure 6.

Figure 7.

Figure 8.

Connecting multiple lemon batteries

1. Build an additional lemon battery and connect it to your first lemon battery. Connect them in a series using alligator clips from the "+" (penny) to "-" (galvanized nail), as illustrated in Figure 8. How many volts do the two combined lemon batteries produce? Record the answer in your graph.

2. Make two additional lemon batteries and connect them all together to create a string of four lemon batteries (see Figure 9). How many volts did the four lemons produce? Record the voltage reading in your graph. This amount should be enough to light up an LED.

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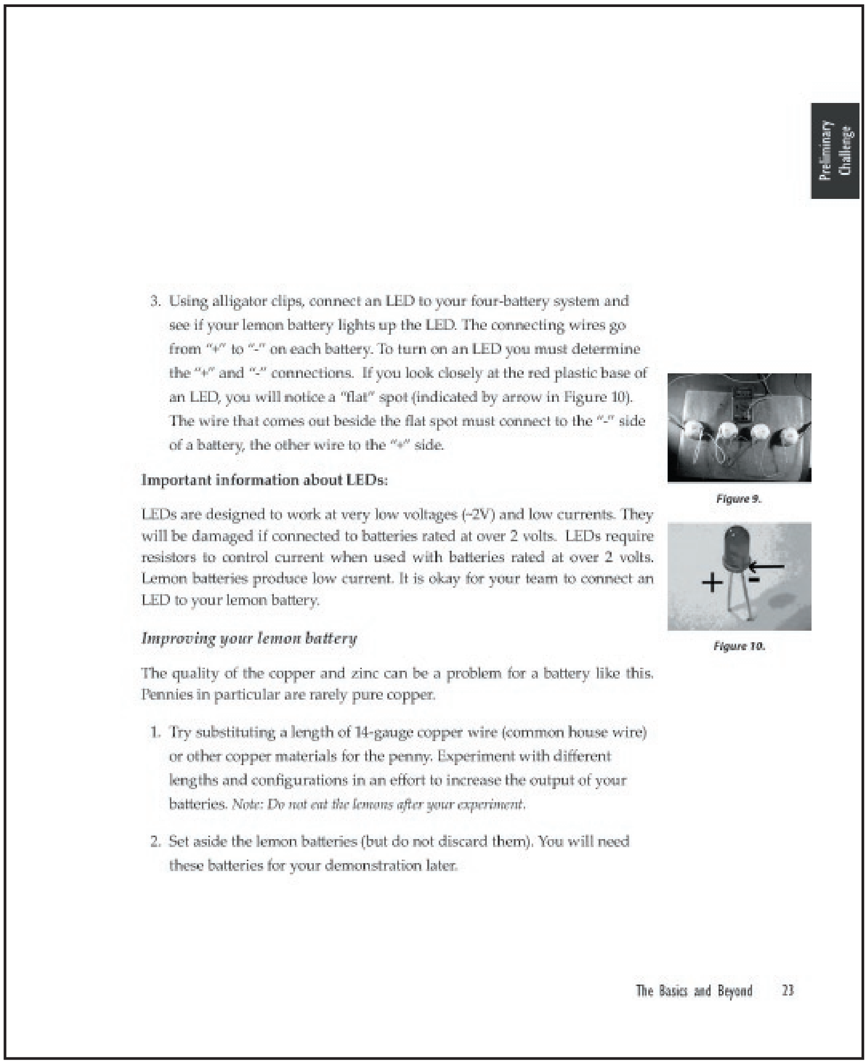
Teaching tips

Ask the students to come up with different uses for the types of batteries that they are creating.



3. Using alligator clips, connect an LED to your four-battery system and see if your lemon battery lights up the LED. The connecting wires go from "+" to "-" on each battery. To turn on an LED you must determine the "+" and "-" connections. If you look closely at the red plastic base of an LED, you will notice a "flat" spot (indicated by arrow in Figure 10). The wire that comes out beside the flat spot must connect to the "-" side of a battery, the other wire to the "+" side.

Figure 9.

Important information about LEDs:

LEDs are designed to work at very low voltages (~2V) and low currents. They will be damaged if connected to batteries rated at over 2 volts. LEDs require resistors to control current when used with batteries rated at over 2 volts. Lemon batteries produce low current. It is okay for your team to connect an LED to your lemon battery.

Figure 10.

Improving your lemon battery

The quality of the copper and zinc can be a problem for a battery like this. Pennies in particular are rarely pure copper.

1. Try substituting a length of 14-gauge copper wire (common house wire) or other copper materials for the penny. Experiment with different lengths and configurations in an effort to increase the output of your batteries. *Note: Do not eat the lemons after your experiment.*

2. Set aside the lemon batteries (but do not discard them). You will need these batteries for your demonstration later.

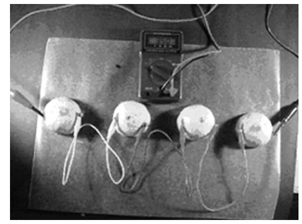


Figure 9.

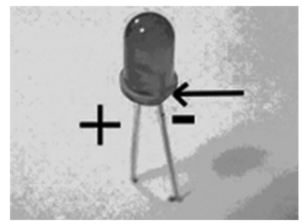


Figure 10.

Teaching Tips

Metal strips can be obtained from scientific supply houses. They are often listed as "electrolytic cells."

Preliminary Challenge

Now that you have completed tests with the lemon battery, conduct additional experiments and extend your knowledge by building a vinegar battery.

Building a vinegar battery

Follow the directions below to construct a vinegar battery:

1. Clean the strips of aluminum and copper metal with steel wool and connect the strips with alligator clips.
2. Pour a 0.1 vinegar solution into a beaker.
3. Without letting the strips touch, place the metal strips into the vinegar solution.
4. Attach one end of the alligator clip from the copper strip to the positive terminal of the multimeter. Attach one end of the alligator clip from the aluminum strip to the negative terminal of the multimeter.
5. Set the multimeter on 2V to 6V range and record the voltage reading in your graph.
6. Now that you have a volt reading for the vinegar battery, switch the multimeter to DC milliamps and identify how many milliamps the vinegar battery is producing. Is there enough current to light an LED?

Preliminary Challenge

Both of the two previous batteries depended upon acid to create a chemical energy source. Build a third type of battery with distilled water and be prepared to describe how it works.

Building a distilled water battery

Follow the directions below to construct a distilled water battery.

1. Clean the strips of zinc and copper metal with steel wool and connect the strips with alligator clips.
2. Pour distilled water into a beaker.
3. Without letting the strips touch, place them in the distilled water.
4. Attach one end of the alligator clip from the copper strip to the positive terminal of the multimeter. Attach one end of the alligator clip from the aluminum strip to the negative terminal of the multimeter.
5. Set the multimeter on 2V to 6V range and record the voltage reading in your graph.
6. Now that you have a volt reading for the distilled water battery, switch the multimeter to DC milliamps and identify how many milliamps the distilled water battery is producing. Is there enough current to light an LED?

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(Adapted from Bob Jones (1983) *Student Activities in Basic Science for Christian Schools* Greenville, SC: University Press.)

Preliminary Challenge

Reflection

1. Explain the kinetic and potential energies found in your device (the device that you created at your station).

Potential	Kinetic
chemical	radiant
nuclear	electrical
stored mechanical	thermal
gravitational	mechanical

2. Which form(s) of energy does your device use? Create a definition or definitions for each form of energy (only forms used in these devices are listed below).

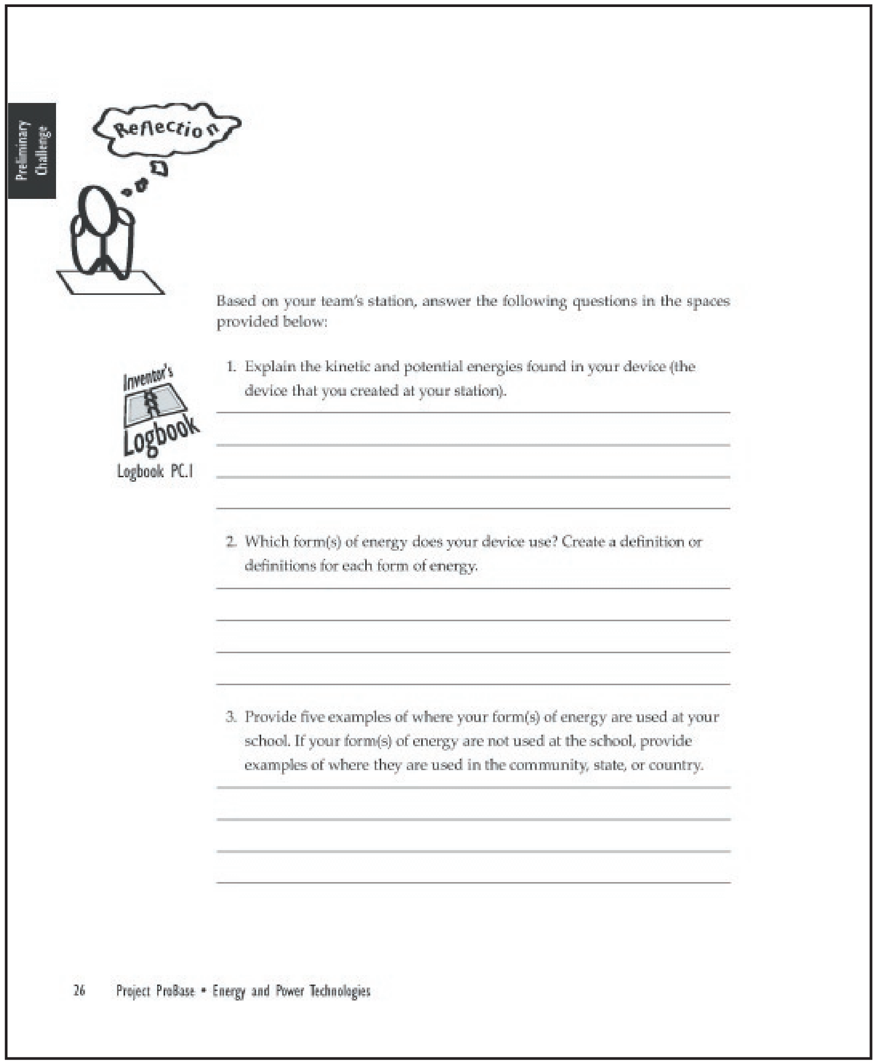
   Chemical: energy stored in atomic bonds and molecules

   Radiant: electromagnetic energy traveling in waves

   Electrical: movement of electrical charges

   Thermal: heat energy

   Mechanical/Motion: energy from the movement of objects from one place to another



Based on your team's station, answer the following questions in the spaces provided below:

1. Explain the kinetic and potential energies found in your device (the device that you created at your station).

2. Which form(s) of energy does your device use? Create a definition or definitions for each form of energy.

3. Provide five examples of where your form(s) of energy are used at your school. If your form(s) of energy are not used at the school, provide examples of where they are used in the community, state, or country.

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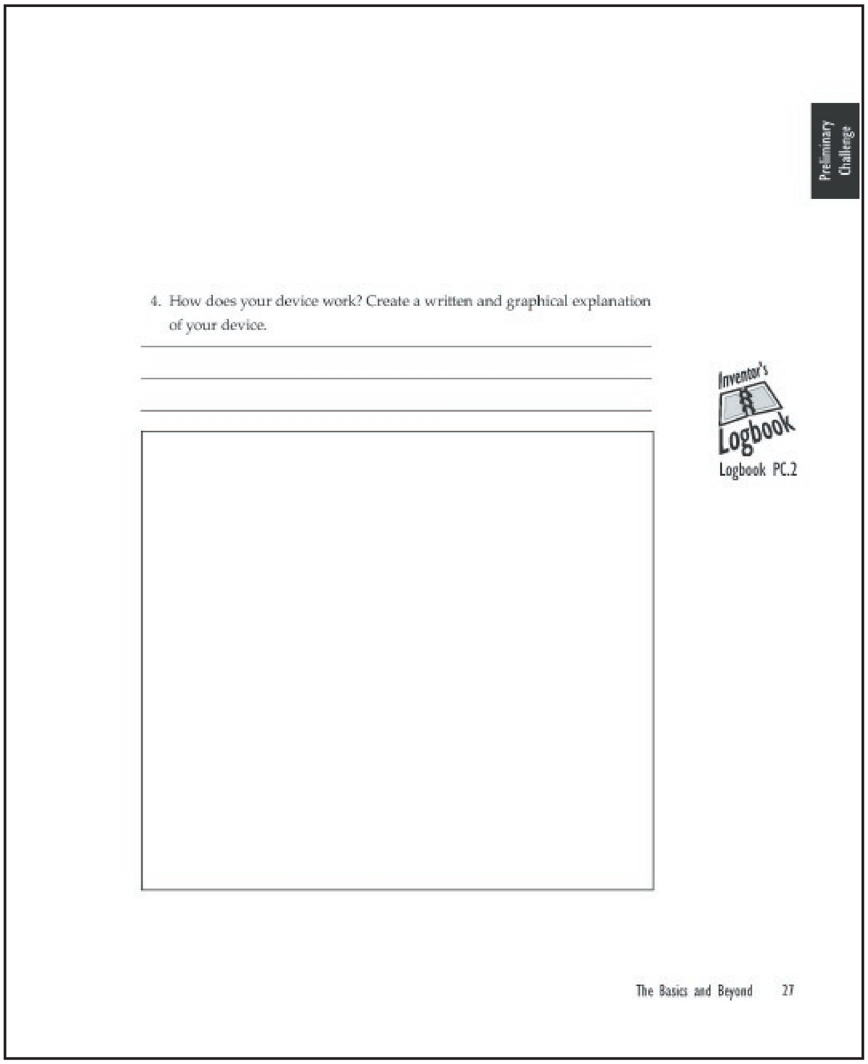
Device	Energy	Explanation
Hero Engine	p, k	chemical (candle) converts to thermal (steam)
Stirling Engine	p, k	chemical (candle) converts to mechanical (tube)
Solar Fan	k, p	radiant (light) converts to mechanical and electrical (motor)
Wind Generator	k,	mechanical (fan) converts to electrical (current)
Battery	p, k	chemical (lemons and vinegar) converts to electrical (current)


Preliminary Challenge

4. How does your device work? Create a written and graphical explanation of your device.

Inventor's Logbook

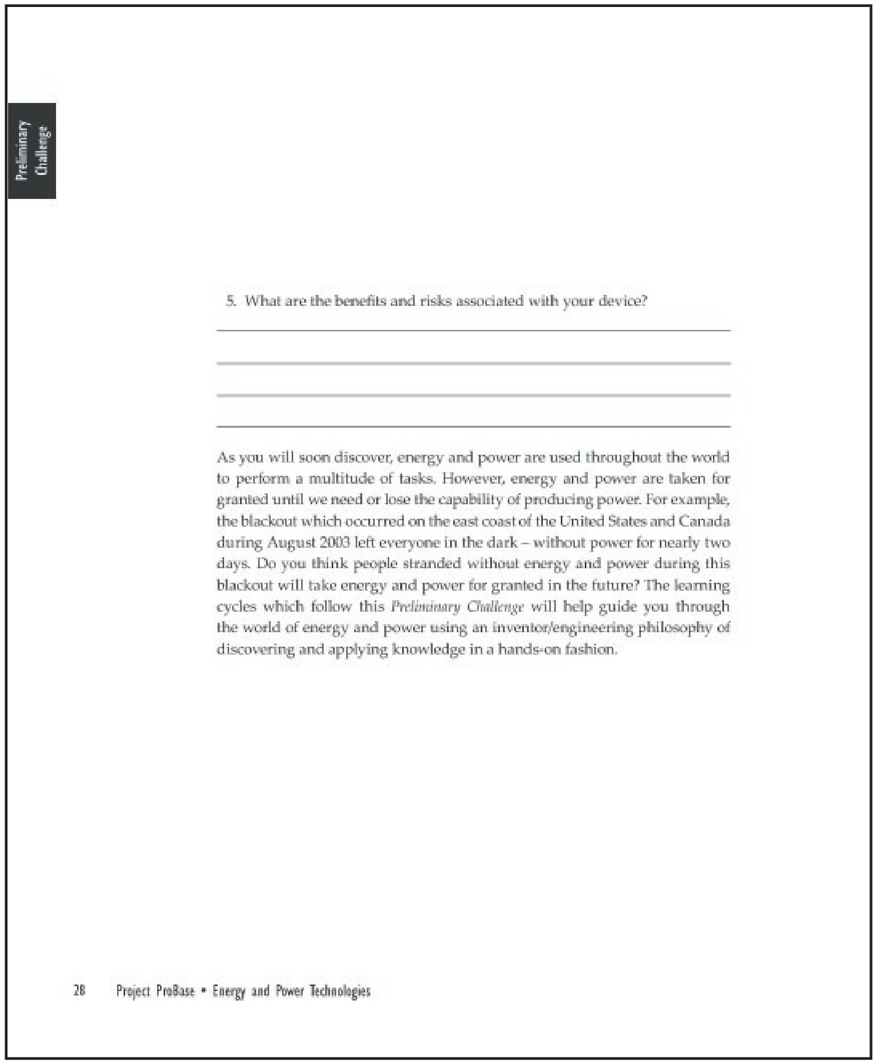
Logbook PC.2

The Basics and Beyond 27

3. Provide five examples of where your form(s) of energy are used at your school. If your form(s) of energy are not used at the school, provide examples of where they are used in the community, state, or country.
   Answers will vary.

4. How does your device work? Create a written and graphical explanation of your device.
   See device explanation on previous page.

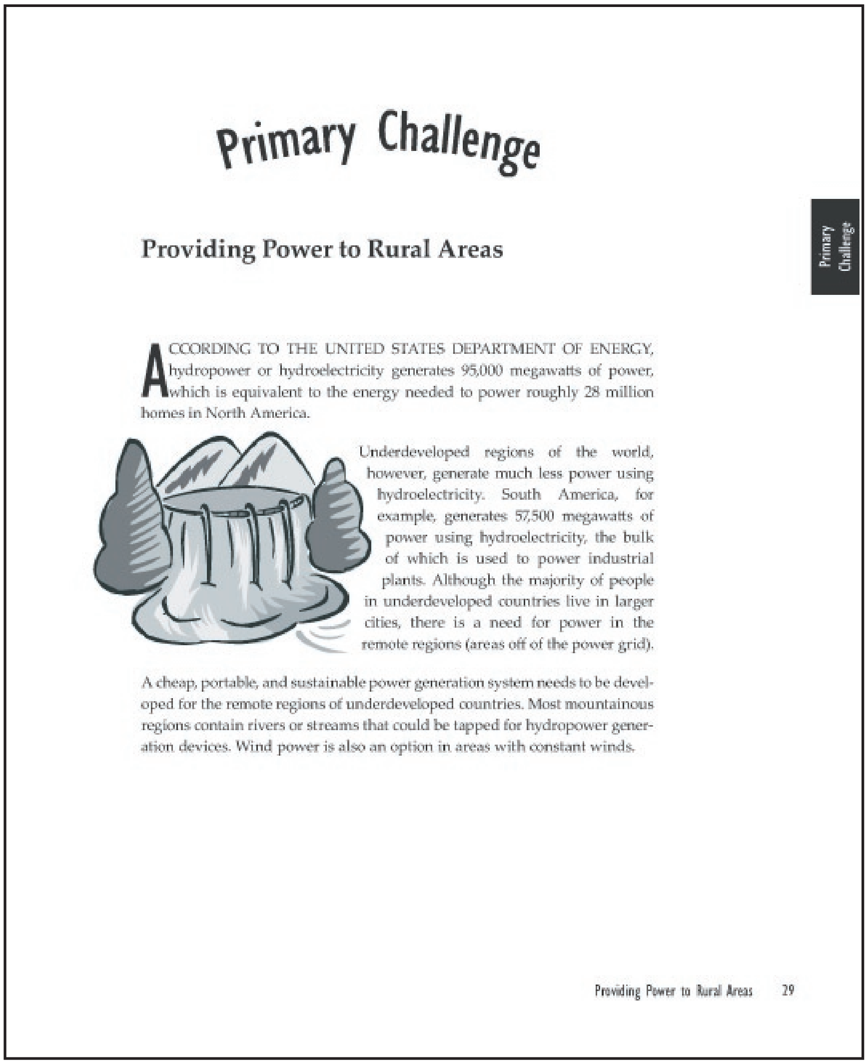
5. What are the benefits and risks associated with your device?
Answers will vary. Students should identify at least one benefit and at least one risk for the device they created. Some answers may be obvious and others may require additional research. (This question may be a good class discussion topic.)



5. What are the benefits and risks associated with your device?

As you will soon discover, energy and power are used throughout the world to perform a multitude of tasks. However, energy and power are taken for granted until we need or lose the capability of producing power. For example, the blackout which occurred on the east coast of the United States and Canada during August 2003 left everyone in the dark – without power for nearly two days. Do you think people stranded without energy and power during this blackout will take energy and power for granted in the future? The learning cycles which follow this *Preliminary Challenge* will help guide you through the world of energy and power using an inventor/engineering philosophy of discovering and applying knowledge in a hands-on fashion.

Notes:



Primary Challenge

Providing Power to Rural Areas

Primary Challenge

ACCORDING TO THE UNITED STATES DEPARTMENT OF ENERGY, hydropower or hydroelectricity generates 95,000 megawatts of power, which is equivalent to the energy needed to power roughly 28 million homes in North America.

Underdeveloped regions of the world, however, generate much less power using hydroelectricity. South America, for example, generates 57,500 megawatts of power using hydroelectricity, the bulk of which is used to power industrial plants. Although the majority of people in underdeveloped countries live in larger cities, there is a need for power in the remote regions (areas off of the power grid).

A cheap, portable, and sustainable power generation system needs to be developed for the remote regions of underdeveloped countries. Most mountainous regions contain rivers or streams that could be tapped for hydropower generation devices. Wind power is also an option in areas with constant winds.

Providing Power to Rural Areas 29

Estimated Number of 50-minute class periods: **10**
(throughout the unit & at the end of the learning cycles)

Providing Power to Rural Areas

Introduction

The *Primary Challenge* should be introduced immediately after students complete the *Preliminary Challenge* so that they can begin to relate concepts developed through the *Preliminary Challenge* and the subsequent learning cycles toward plausible solutions to this challenge. You should spend a portion of class time addressing any questions teams have about the *Primary Challenge* at this time; however, you will likely answer many questions with a comment like, "You will complete a number of learning cycles in the coming weeks that will prepare you to answer that question." At this time, you should ask students to generate questions that they will need answered in order to solve the *Primary Challenge*.

After the students have generated these questions, post them in a prominent place in the classroom (using the poster) so that students can refer back to them during the unit. There are short breaks between learning cycles and approximately two weeks at the conclusion of the last learning cycle where student teams can work on the solution for the *Primary Challenge*. Students will be asked to reflect on this challenge as part of each learning cycle in a section titled *Preparing for the Challenge*.

Equipment, Materials and Facility Requirements

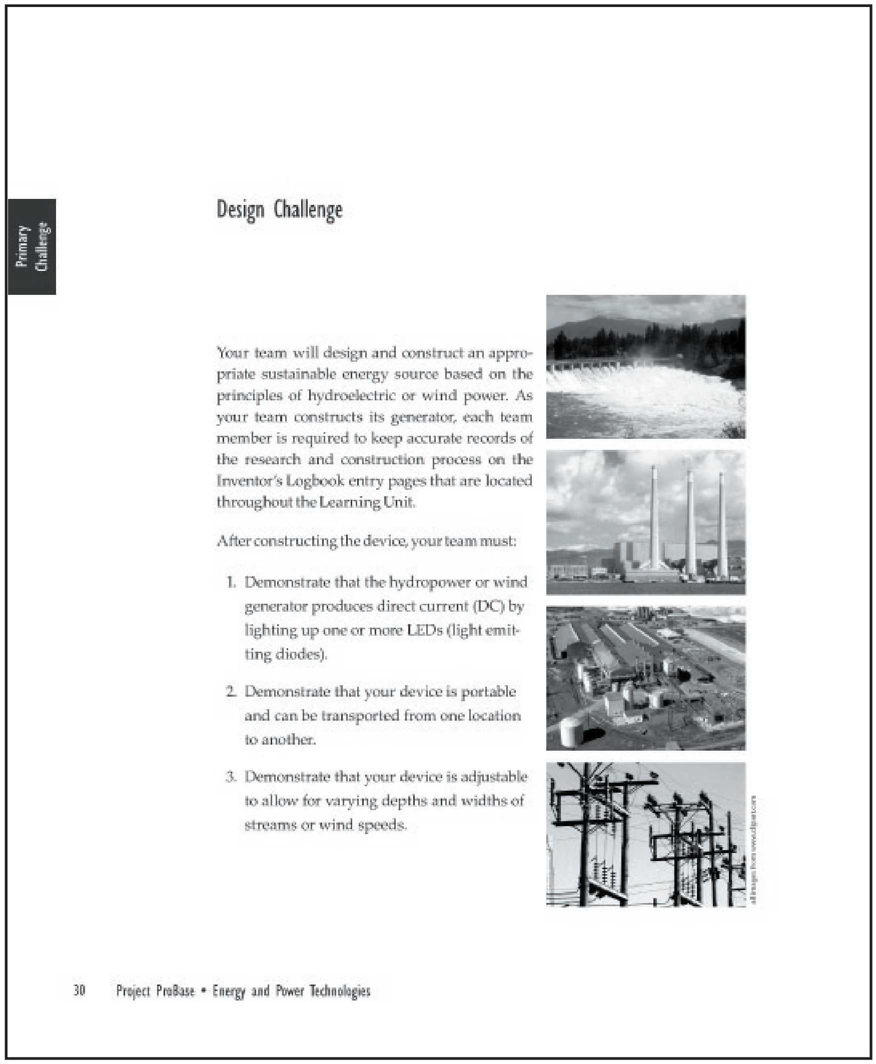
No special facility requirements are needed to complete this *Primary Challenge*. However, you should begin preparing for this challenge by locating a suitable place to set up a testing area for the solutions. This area should be close to a source of running water or in high winds. If possible, this area should be outside to reduce the amount of clean up necessary after testing.

You may need to construct a testing apparatus for the hydropower generators. This apparatus can be constructed from a piece of plastic rain gutter and a garden hose. The goal is to create a simulated river by flowing as much water down the gutter as possible. Your design may need to be modified and flexible to accommodate different solutions to the challenge. You may want to affix a mounting plate to the side of the testing apparatus to which all teams will mount their respective generators during the testing phase.

Based upon how your students solve the *Primary Challenge*, materials may need to be ordered or acquired from earlier learning cycles or outside sources. You may want to anticipate thue use of electromagnetic wire and magnets for creating coils. Additional materials for solving this *Primary Challenge* should be found in your lab.

Design Challenge

Students are required to work as a team (as assigned by you) to design and construct an appropriate sustainable energy source based on the principles of hydroelectric or wind power. As the teams construct



Primary Challenge

Design Challenge

Your team will design and construct an appropriate sustainable energy source based on the principles of hydroelectric or wind power. As your team constructs its generator, each team member is required to keep accurate records of the research and construction process on the Inventor's Logbook entry pages that are located throughout the Learning Unit.

After constructing the device, your team must:

1. Demonstrate that the hydropower or wind generator produces direct current (DC) by lighting up one or more LEDs (light emitting diodes).
2. Demonstrate that your device is portable and can be transported from one location to another.
3. Demonstrate that your device is adjustable to allow for varying depths and widths of streams or wind speeds.

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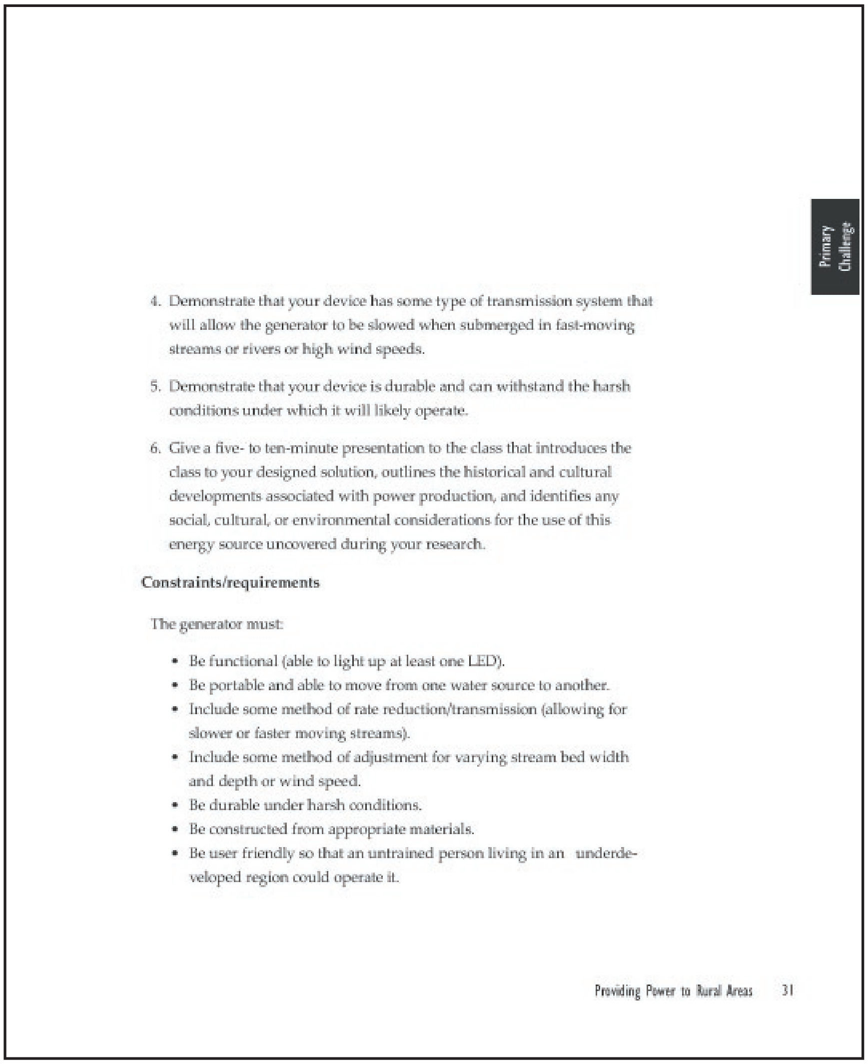
their respective generators, each team member is required to keep accurate records of the research and construction process on the Inventor's Logbook entry pages in each learning unit.

After constructing the device, the teams must:

1. Demonstrate that the hydropower or wind generator produces direct current (DC) by lighting up one or more LEDs (light emitting diode).
2. Demonstrate that the device is portable and can be transported from one location to another.
3. Demonstrate that the device is adjustable to allow for varying depths and widths of streams or variable wind speeds.


Primary Challenge

4. Demonstrate that your device has some type of transmission system that will allow the generator to be slowed when submerged in fast-moving streams or rivers or high wind speeds.

5. Demonstrate that your device is durable and can withstand the harsh conditions under which it will likely operate.

6. Give a five- to ten-minute presentation to the class that introduces the class to your designed solution, outlines the historical and cultural developments associated with power production, and identifies any social, cultural, or environmental considerations for the use of this energy source uncovered during your research.

Constraints/requirements

The generator must:

- Be functional (able to light up at least one LED).
- Be portable and able to move from one water source to another.
- Include some method of rate reduction/transmission (allowing for slower or faster moving streams).
- Include some method of adjustment for varying stream bed width and depth or wind speed.
- Be durable under harsh conditions.
- Be constructed from appropriate materials.
- Be user friendly so that an untrained person living in an underdeveloped region could operate it.

Providing Power to Rural Areas 31

4. Demonstrate that the device has some type of transmission system that will allow the generator to be slowed when submerged in fast-moving streams or rivers or high wind speeds.

5. Demonstrate that the device is durable and can withstand the harsh conditions under which it will likely operate.

6. Give a five- to-ten minute presentation to the class that introduces the class to the designed solution, outlines the historical and cultural developments associated with power production, and identifies any social, cultural, or environmental considerations for the use of this energy source uncovered during your research.

Additionally, the student teams are required to remain within the following constraints and requirements:

The generator must:

- Be functional (able to light up at least one LED).
- Be portable and able to move from one water source to another.
- Include some method of rate reduction/transmission (allowing for slower or faster moving streams).
- Include some method of adjustment for varying stream bed width and depth or wind speed.
- Be durable under harsh conditions.
- Be constructed from appropriate materials.
- Be user friendly so that an untrained person living in an underdeveloped region would be able to operate it.

Primary Challenge

Preparing for the Primary Challenge

The *Primary Challenge* requires the students to design and construct a working power generator that lights up at least one LED (light emitting diode). Students will learn important concepts necessary to design an appropriate solution to the challenge.

After you have assigned teams, each team will need some time to work together. It is recommended that you provide one class period at this time for teams to begin working together on the following task:

> Research wind or water power generators. They should be looking for articles that describe how these devices work, where they are used, how they have impacted rural societies, and how they impact the environment.

The choice between creating a wind or water generator will depend upon the accessibility of a location to test the generator. A high-powered fan can be used to test the wind generator and a stream can be used to test the water generator.

Teaching tips

You will have to provide assistance throughout this *Primary Challenge*, but the bulk of the work should come from the students. For example, you may need to teach students how to rectify an AC current to DC. In addition, since the *Primary Challenge* focuses on appropriate uses of technology, additional student investigation and classroom discussion may need to take place so that students fully understand what "appropriate technology" or "sustainable development" is meant to accomplish. There are a number of great resources related to these fields of study on the Internet. By using search terms like "appropriate technology," the "decision sciences," "sustainable development," or "science/technology/society" you will be able to find any number of resources related to the field. You are encouraged to insert a short lesson related to these fields of study into the unit.

Teaching tips

After completing the *Preliminary Challenge*, you will need to divide your class into teams. After observing students during the *Preliminary Challenge* you should have a better idea for effective teams.

Teaching tips

The students' solutions must convert the linear motion of wind or water to the rotary motion required to generate electricity. Three possible solutions include constructing a water wheel, reaction turbine, or impulse turbine. Teams should identify these and other possible solutions on their own and determine the best approach to the *Primary Challenge.*

Teaching Tips

In a constructivist-based Learning Unit, it is important to focus on conceptual development. Therefore, it will be important for your class to stop and check for understanding from time to time throughout this unit. The students' Inventor's Logbook entries will serve as one means to check student progress on a regular basis. Additional strategies that may help you keep the students focused on their conceptual development include:

- Creating a large poster with the key concepts and/or enduring understandings and placing it in a prominent spot in your classroom (An example layout can be found in the appendix).
- Breaking into *Primary Challenge* teams and identif what students know and what they need to know to solve the *Primary Challenge*. Compile their thoughts through a discussion and create a large class display of what they know and what they need to know. Require the students (or teams) to "check off" the questions that have been answered during the course of the Learning Unit (throughout the nine-week period).
- Having your students create concept maps of the unit in the Inventor's Logbook entry forms located at the end of their texts. Use the concept map at the beginning of this Instructor guide (p. xi) as a model.

Resources:

water wheel kits and pictures

http://www.waterwheelfactory.com

encylopedia

http://encarta.msn.com/encyclopedia_761563866/Turbine.html
http://inventors.about.com/library/inventors/blwaterwheel.htm

wind energy

http://sln.fi.edu/tfi/units/energy/windguide.html
http://solstice.crest.org/renewables/re-kiosk/wind/index.shtml

Student Assessment

A rubric has been placed in the Instructor's Guide and the Student's Guide. The rubric is designed as a tool for assessing students' performance in designing a solution and creating an efficient hydroelectric or wind generator capable of generating as much power as possible using a variable scale. Based upon your situation, please feel free to modify the scoring guidelines. The rubric should be discussed and shared with students at the beginning of the unit, focusing on the necessary requirements for the *Primary Challenge* (artifact and written documentation). It is also recommended that you post this rubric in a prominent place in the classroom/laboratory so that student teams can refer to it during the nine-week period.

Primary Challenge Rubric

Element	Criteria				Points
Point Values	40	30	20	10	
Primary Challenge Product	Completed product is fully functional and addresses all criteria, parameters, and equipment specifications set forth in the *Primary Challenge*.	Completed product is functional and meets most criteria, parameters, and equipment specifications set forth in the *Primary Challenge*.	Completed product represents a serious attempt to solve the *Primary Challenge* but does not address many of the stated criteria, parameters, or specifications.	Product is not complete or does not function well and does not meet stated criteria, parameters, or specifications.	
Number of LEDs Activated by Generator	Six or more LEDs were activated by generator.	Four to five LEDs were activated by generator	Two to three LEDs were activated by generator.	Only one LED was activated by generator.	
				Sub-total	
Point Values	15	10	5	2	
Drawings, Diagrams and sketches	Drawings, diagrams, or sketches clearly illustrate an understanding of all requirements, criteria, or specifications; uses proper format and was completed electronically.	Drawings, diagrams, or sketches illustrate needed information, but do not address all stated requirements, specifications, or criteria. Completed using an electronic format.	Drawings, diagrams, or sketches illustrate needed information, but do not address all stated requirements, specifications, or criteria. Did not utilize an electronic format (hand drawn).	Drawings, diagrams, or sketches do not illustrate all needed information. Illustrations are incomplete or poorly presented.	
Research & Development	Clear evidence of a comprehensive research and development effort was provided.	Research and development was conducted while solving the *Primary Challenge*, but documentation was marginal.	Some research and development techniques were used while attempting to solve the *Primary Challenge*, but were not clearly documented.	Minimal research and development techniques were used while attempting to solve the *Primary Challenge*. Documentation was marginal.	
Documentation	As directed, the team responded to questions and/or maintained comprehensive records, logs, and other notations of activities while completing the *Primary Challenge*.	Team responded to questions and/or maintained topical records, logs, and other notations of activities while completing the *Primary Challenge*.	Team responded to most questions and/or maintained some records, logs, and other notations of activities while completing the *Primary Challenge*.	Team marginally responded to questions and did not maintain records, logs, and other notations of activities while completing the *Primary Challenge*.	
Presentation	Presentation demonstrates a full grasp of the major concepts, addresses all stated presentation requirements, and conforms to time limit constraints.	Presentation demonstrates significant understanding of major concepts, addresses most presentation requirements, and conforms to time limitations.	Presentation topically addresses some of the concepts delivered in this unit, but does not conform to stated presentation guidelines and/or time limits.	Presentation does not demonstrate a grasp of the major concepts delivered in this unit and/or does not address stated presentation guidelines or time limits.	
				Total Points	

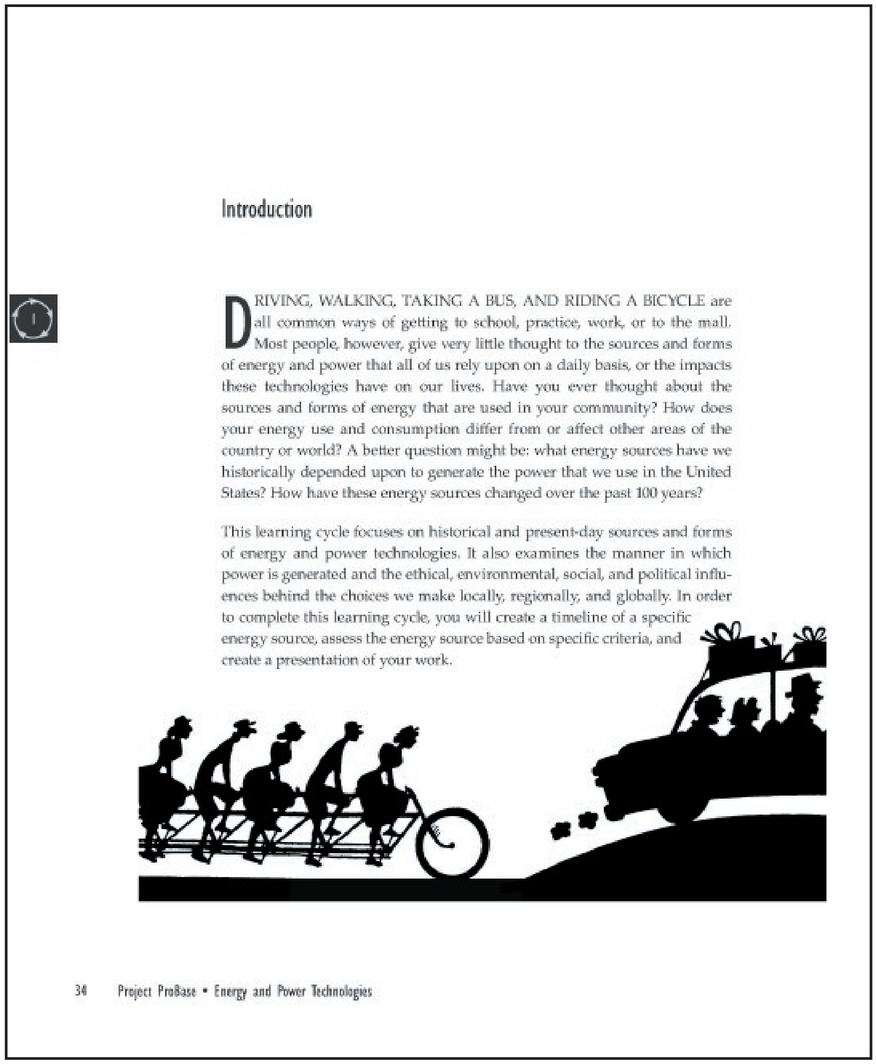
Learning Cycle One

Energy and Power, So What?

Energy and Power, So What?

Introduction

This learning cycle focuses on historical and present-day sources and forms of energy and power technologies. While completing this learning cycle, students will be engaged in issues related to the ethical, environmental, social, and political influences behind the energy and power choices we make. Students will also examine how energy and power decisions made locally impact others regionally, nationally, and globally. In order to complete this learning cycle, students will create a timeline of a specific energy source, assess the energy source based on specific criteria, and create a presentation of their work.



Introduction

DRIVING, WALKING, TAKING A BUS, AND RIDING A BICYCLE are all common ways of getting to school, practice, work, or to the mall. Most people, however, give very little thought to the sources and forms of energy and power that all of us rely upon on a daily basis, or the impacts these technologies have on our lives. Have you ever thought about the sources and forms of energy that are used in your community? How does your energy use and consumption differ from or affect other areas of the country or world? A better question might be: what energy sources have we historically depended upon to generate the power that we use in the United States? How have these energy sources changed over the past 100 years?

This learning cycle focuses on historical and present-day sources and forms of energy and power technologies. It also examines the manner in which power is generated and the ethical, environmental, social, and political influences behind the choices we make locally, regionally, and globally. In order to complete this learning cycle, you will create a timeline of a specific energy source, assess the energy source based on specific criteria, and create a presentation of your work.

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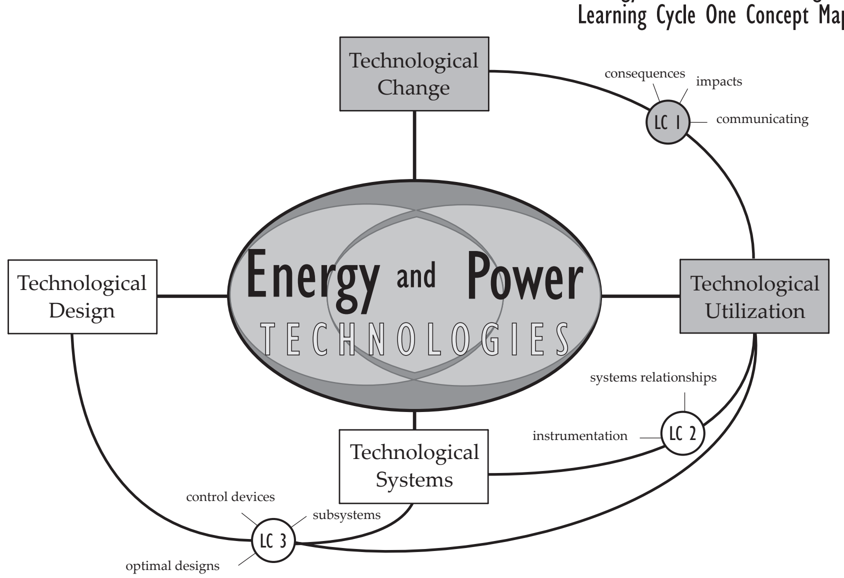
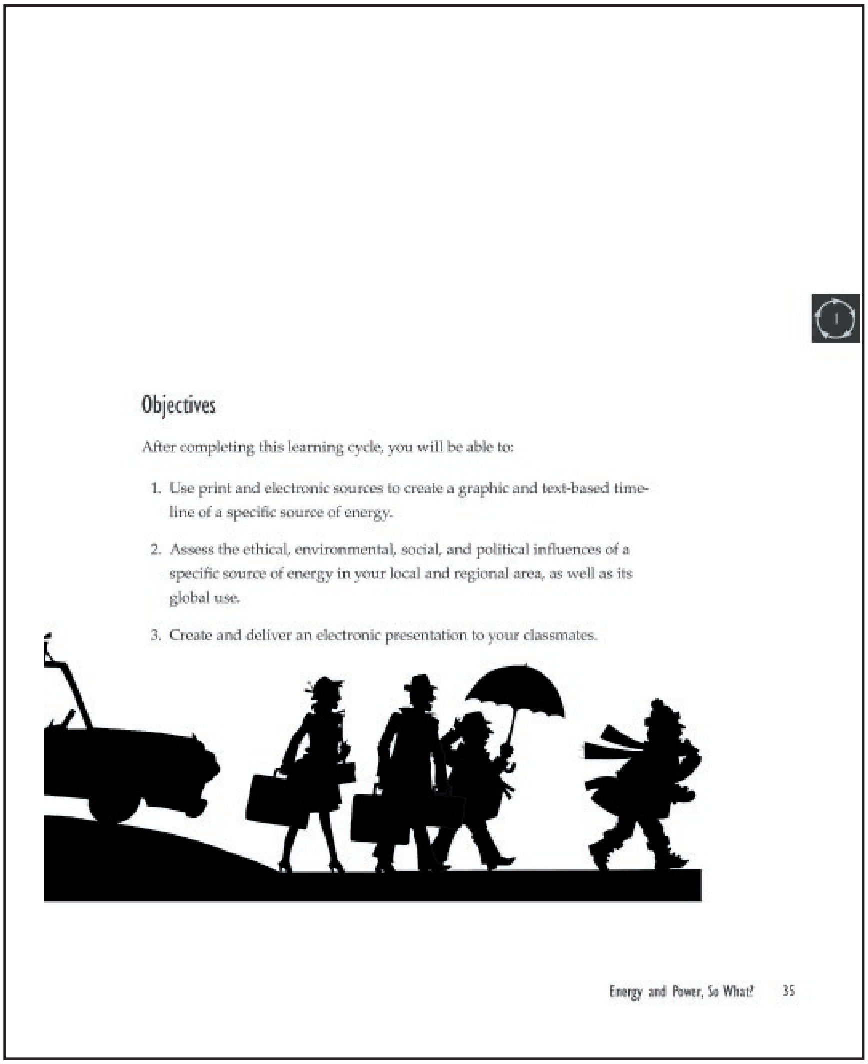
Objectives and Essential Questions

After completing this learning cycle, students will be able to:

1. Use print and electronic sources to create a graphic and text-based timeline of a specific source of energy.
   Essential Question 3a: What are some of the unforeseen consequences of specific technological changes throughout history?

Energy and Power Technologies
Learning Cycle One Concept Map





Objectives

After completing this learning cycle, you will be able to:

1. Use print and electronic sources to create a graphic and text-based time-line of a specific source of energy.
2. Assess the ethical, environmental, social, and political influences of a specific source of energy in your local and regional area, as well as its global use.
3. Create and deliver an electronic presentation to your classmates.

Energy and Power, So What? 35

2. Assess the ethical, environmental, social, and political influences of a specific source of energy in your local and regional area, as well as its global use.

Essential Question 3b: How can a technology cause both good and harm and how do humans prepare for or respond to these impacts?

3. Create and deliver an electronic presentation to the rest of the class.

Essential Question 9a: How is technology used to control devices and systems and provide information to humans?

Facility Requirements

No special facility requirements are neededas long as students have access to computers with Internet access.

Equipment and Materials

Based on a class of 28 students:

Computer with Internet access for each group

Word processing software for each group

Microsoft PowerPoint® or other presentation software for each group

Printer (large and small formats if possible)

Poster board (if appropriate for *Expansion* activity)

Television/VCR (if appropriate for *Expansion* activity – "Meltdown at Three Mile Island" Video)

(4) Ceramic magnets

200 feet of #30 magnet wire

LED or miniature incandescent lamp

16d nail

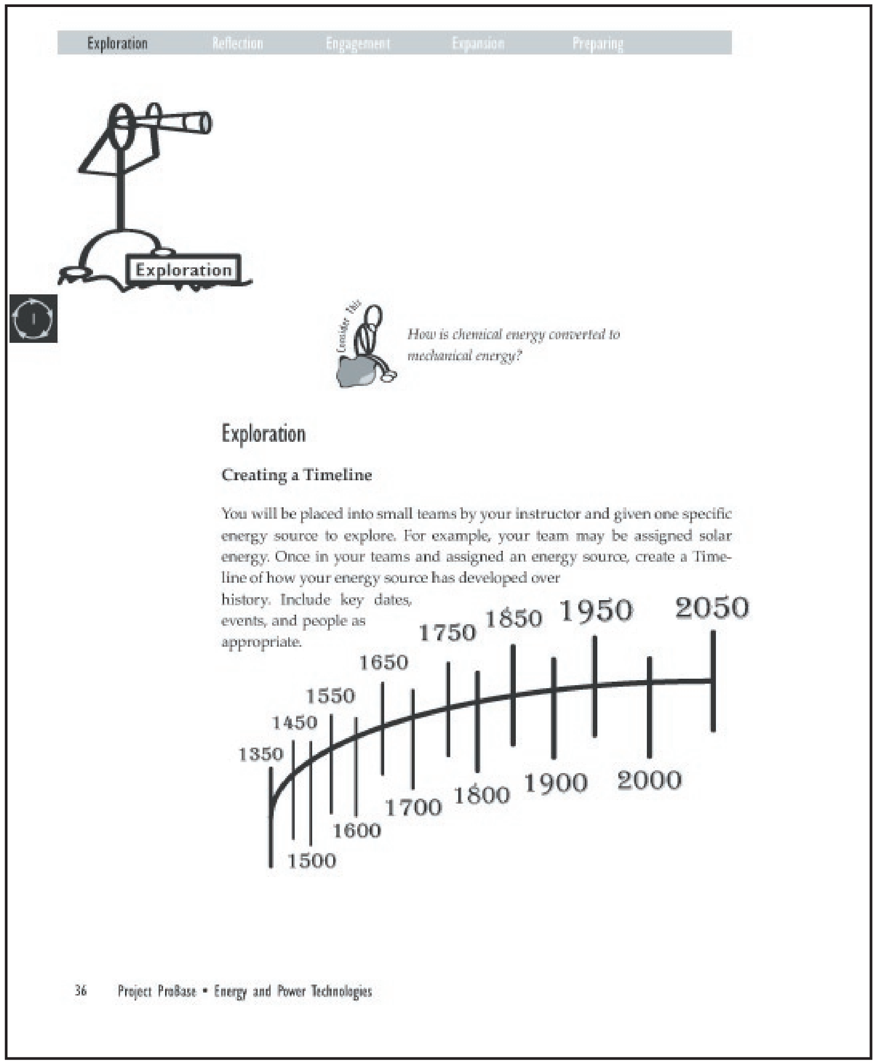
Miscellaneous wood and sand-paper

Electric or hand-operated drill

Estimated number of 50-minute class periods:8

Suggested Daily Outline

Day One	Day Two
Introduction, *Exploration*	*Exploration*
Day Three	**Day Four**
Reflection, Discussion	*Engagement* research
Day Five	**Day Six**
Engagement	*Engagement* presentations
Day Seven	**Day Eight**
Engagement presentations	*Preparing for the Challenge*


Exploration Reflection Engagement Expansion Preparing

Exploration

Consider This

How is chemical energy converted to mechanical energy?

Exploration

Creating a Timeline

You will be placed into small teams by your instructor and given one specific energy source to explore. For example, your team may be assigned solar energy. Once in your teams and assigned an energy source, create a Timeline of how your energy source has developed over history. Include key dates, events, and people as appropriate.

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Exploration

There are several sources of renewable and nonrenewable energy, such as–*solar, nuclear, hydrogen gas, fossil fuels (e.g., coal, natural gas, and petroleum), wind, tidal, geothermal, hydropower, chemical, and biomass.*

Exploration Reflection Engagement Expansion Preparing

Reflection

Based on the energy source that your instructor provided, answer the following questions in the Inventor's Logbook spaces below:

Inventor's Logbook

Logbook 1.1

1. What ethical considerations had to or will need to be considered with respect to your given energy source? In other words, who stands to benefit from the use of this energy source and who stands to lose?

2. What environmental impacts (good and bad) occurred or will occur through the use of this energy source?

3. Are there any social ramifications? In other words, will the use of this technology cause changes in our society?

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Teaching Tips

Each source of energy should be assigned to a team of students (teams of three students or less are best). In the *Exploration* section of this learning cycle, each team will need to have Internet access and be able to use various software programs (e.g., Microsoft Word® and Microsoft PowerPoint).

The energy source timeline the students create should be detailed and contain information from the time humans inhabited the earth to the present day. After students conduct research on their respective timelines, they should prepare a presentation using Microsoft PowerPoint or other professional presentation tools.

Teaching Tips

Students are provided five questions in the *Reflection* section. These questions should guide their inquiry on the Internet, since they will need this information for their presentation.

You may need to help focus the students on searching the Internet with key words. It is entirely up to you how the teams output their timeline (e.g., electronic or on large format paper). Stress to the students that this timeline needs to be neat and accurate.

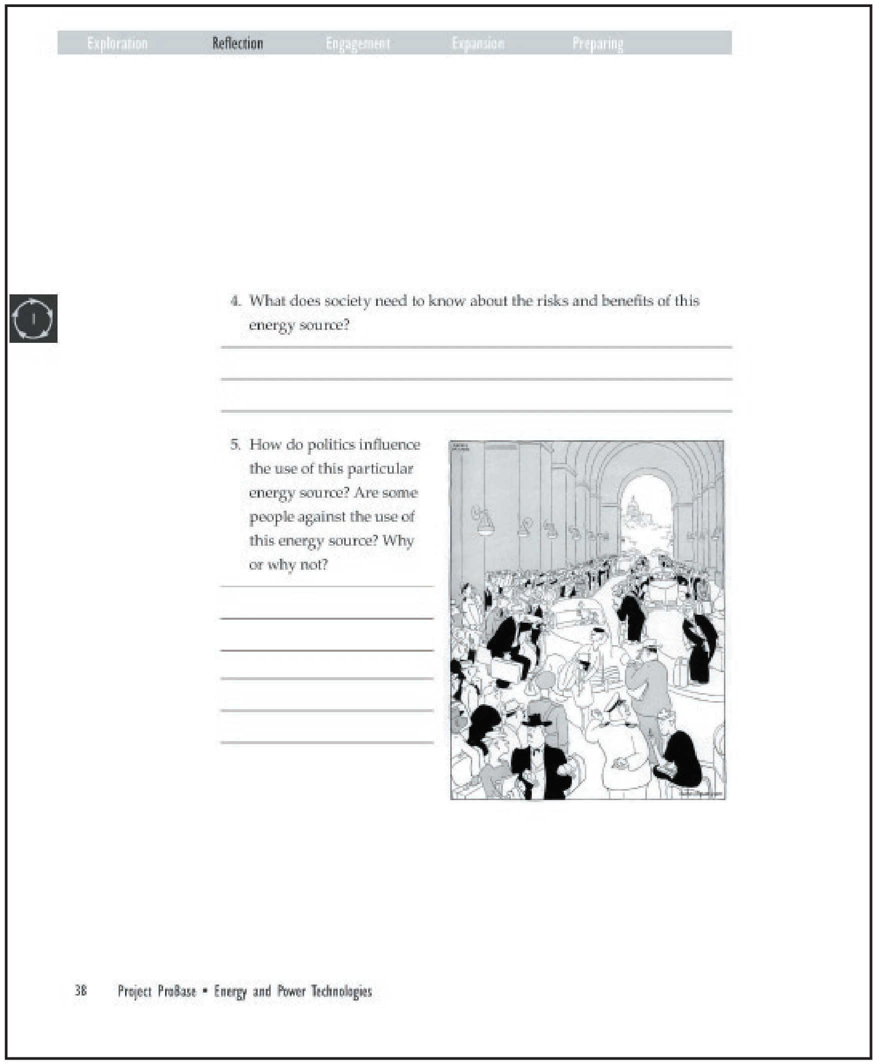
Reflection

Students are provided opportunities to reflect on the activities throughout this Learning Unit. Students are asked to respond to the following questions and are provided space within their student texts to write their responses.

1. What ethical considerations have been or will need to be considered with respect to your given energy source? In other words, who stands to benefit from the use of this energy source and who stands to lose?
   Answers will vary.

2. What environmental impacts (good and bad) occurred or will occur through the use of this energy source?
   Answers will vary.

3. Are their any social ramifications? In other words, will the use of this technology cause or impact changes in our society?
   Answers will vary.



Exploration Reflection Engagement Expansion Preparing

4. What does society need to know about the risks and benefits of this energy source?

5. How do politics influence the use of this particular energy source? Are some people against the use of this energy source? Why or why not?

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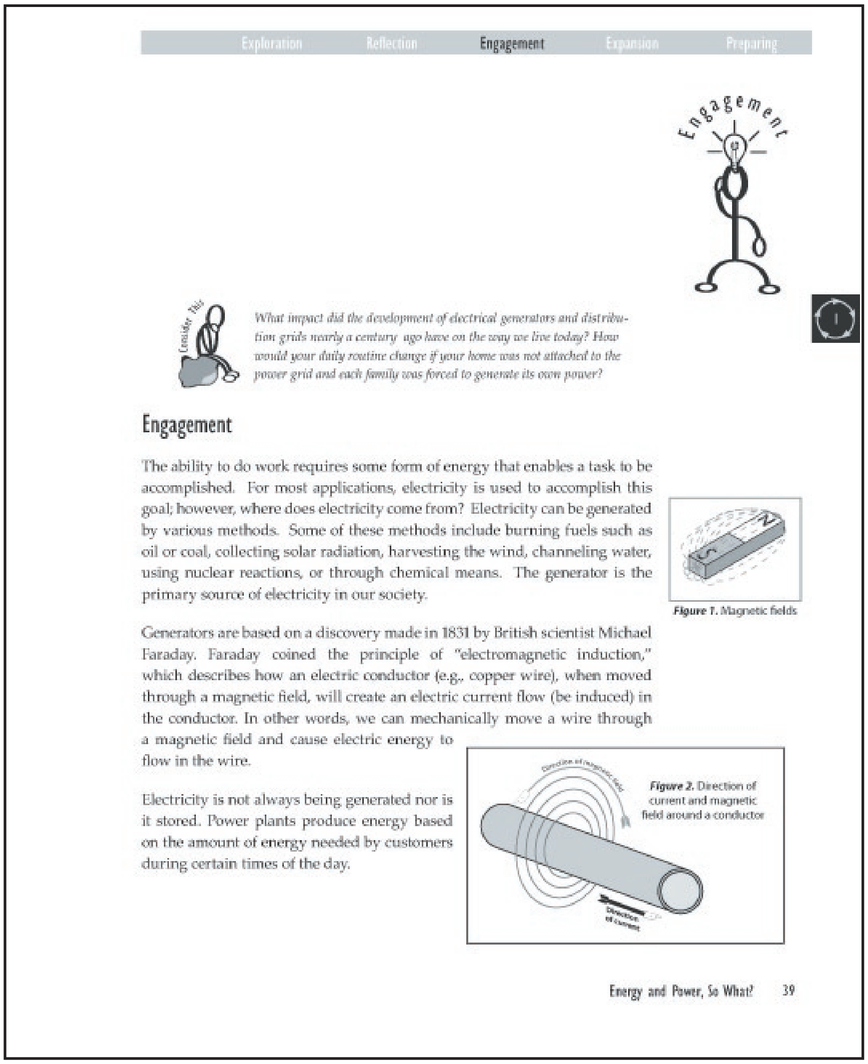
4. What does society need to know about the risks and benefits of this energy source?
   Answers will vary.

5. How do politics influence the use of this particular energy source? Are some people against the use of this energy source? Why or why not?
   Answers will vary.


Exploration Reflection Engagement Expansion Preparing

Engagement

Consider This

What impact did the development of electrical generators and distribution grids nearly a century ago have on the way we live today? How would your daily routine change if your home was not attached to the power grid and each family was forced to generate its own power?

Engagement

The ability to do work requires some form of energy that enables a task to be accomplished. For most applications, electricity is used to accomplish this goal; however, where does electricity come from? Electricity can be generated by various methods. Some of these methods include burning fuels such as oil or coal, collecting solar radiation, harvesting the wind, channeling water, using nuclear reactions, or through chemical means. The generator is the primary source of electricity in our society.

Figure 1. Magnetic fields

Generators are based on a discovery made in 1831 by British scientist Michael Faraday. Faraday coined the principle of "electromagnetic induction," which describes how an electric conductor (e.g., copper wire), when moved through a magnetic field, will create an electric current flow (be induced) in the conductor. In other words, we can mechanically move a wire through a magnetic field and cause electric energy to flow in the wire.

Electricity is not always being generated nor is it stored. Power plants produce energy based on the amount of energy needed by customers during certain times of the day.

Figure 2. Direction of current and magnetic field around a conductor

Energy and Power, So What? 39

Engagement

Teaching Tips

During this phase of the learning cycle, student teams will be learning about work, energy generation, and some of the important historical figures in the field of energy and power. You may want to begin the *Engagement* with a discussion of "work."

Work can be described as the use of energy to accomplish a task. For most applications, electricity is used to accomplish this goal. From there, you might want to lead a discussion about where electricity comes from. You may even want to ask students to identify exactly where their electricity is generated locally. You could expand on this conversation by discussing the benefits and drawbacks of the various fuels used to produce electricity.

Electricity can be generated by various methods. Some of these methods include burning fuels such as oil or coal, collecting solar radiation, harvesting the wind, channeling water, using nuclear reactions, or through chemical means.

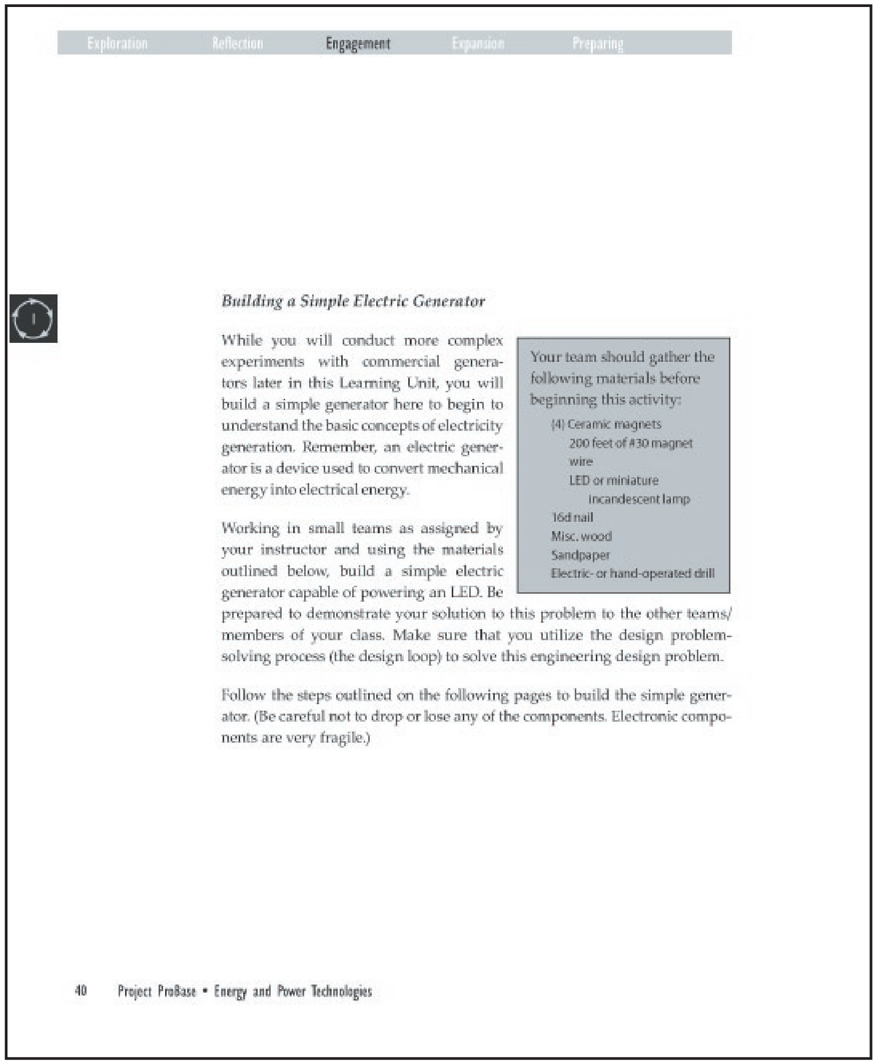
Students will be asked to build a simple generator. You may want to introduce this concept by providing a brief history lesson related to energy generation. All generators are based on a discovery in the year 1831 by British Scientist Michael Faraday. Faraday coined the principle of "electromagnetic induction," which describes how as an electric conductor, like a copper wire, is moved through a magnetic field, electric current will flow (be induced) in the conductor.

Next, the students will work in teams to build a simple electric generator capable of powering an LED. You will need to provide the student teams with the following materials:

(4) Ceramic magnets

- 200 feet of #30 magnet wire
- LED or miniature incandescent lamp
- 16d nail
- Miscellaneous wood and sandpaper
- Electric or hand-operated drill

The students will also need to be prepared to demonstrate their team's solution to the rest of the class. Make sure that the students utilize the design problem solving process (the design loop) to solve this engineering design problem.



Exploration Reflection Engagement Expansion Preparing

Building a Simple Electric Generator

While you will conduct more complex experiments with commercial generators later in this Learning Unit, you will build a simple generator here to begin to understand the basic concepts of electricity generation. Remember, an electric generator is a device used to convert mechanical energy into electrical energy.

Your team should gather the following materials before beginning this activity:
(4) Ceramic magnets
200 feet of #30 magnet wire
LED or miniature incandescent lamp
16d nail
Misc. wood
Sandpaper
Electric- or hand-operated drill

Working in small teams as assigned by your instructor and using the materials outlined below, build a simple electric generator capable of powering an LED. Be prepared to demonstrate your solution to this problem to the other teams/members of your class. Make sure that you utilize the design problem-solving process (the design loop) to solve this engineering design problem.

Follow the steps outlined on the following pages to build the simple generator. (Be careful not to drop or lose any of the components. Electronic components are very fragile.)

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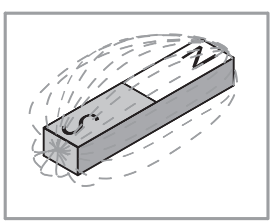


Figure 1. Magnetic fields

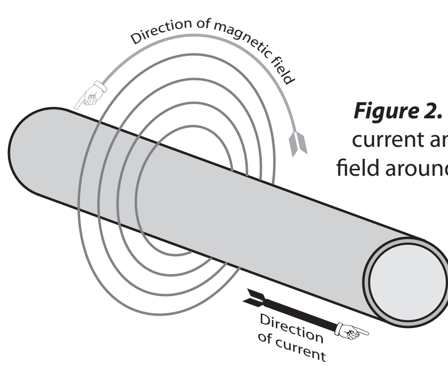
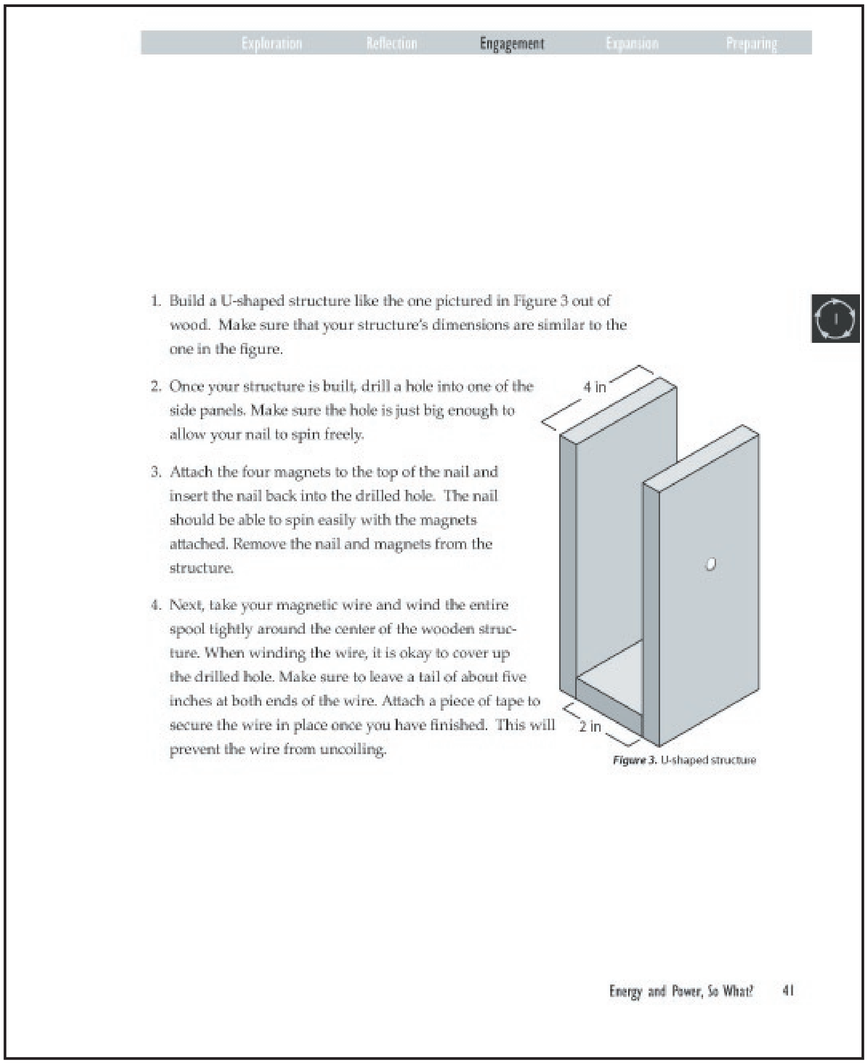


Figure 2. Direction of current and magnetic field around a conductor



Exploration Reflection Engagement Expansion Preparing

1. Build a U-shaped structure like the one pictured in Figure 3 out of wood. Make sure that your structure's dimensions are similar to the one in the figure.
2. Once your structure is built, drill a hole into one of the side panels. Make sure the hole is just big enough to allow your nail to spin freely.
3. Attach the four magnets to the top of the nail and insert the nail back into the drilled hole. The nail should be able to spin easily with the magnets attached. Remove the nail and magnets from the structure.
4. Next, take your magnetic wire and wind the entire spool tightly around the center of the wooden structure. When winding the wire, it is okay to cover up the drilled hole. Make sure to leave a tail of about five inches at both ends of the wire. Attach a piece of tape to secure the wire in place once you have finished. This will prevent the wire from uncoiling.

4 in

2 in

Figure 3. U-shaped structure

Energy and Power, So What? 41

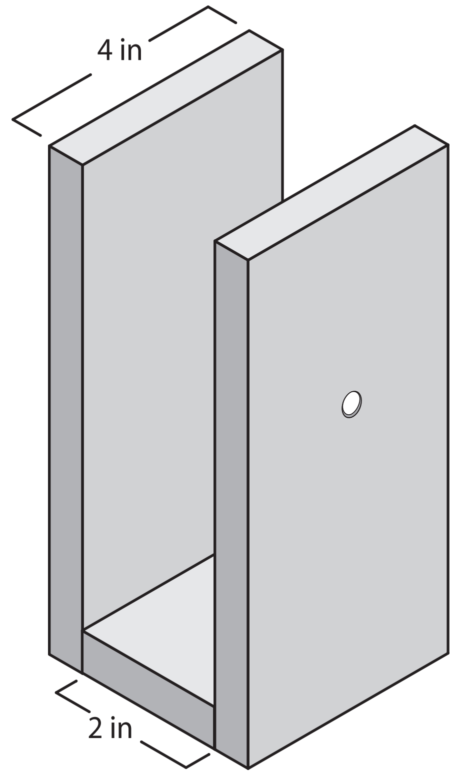
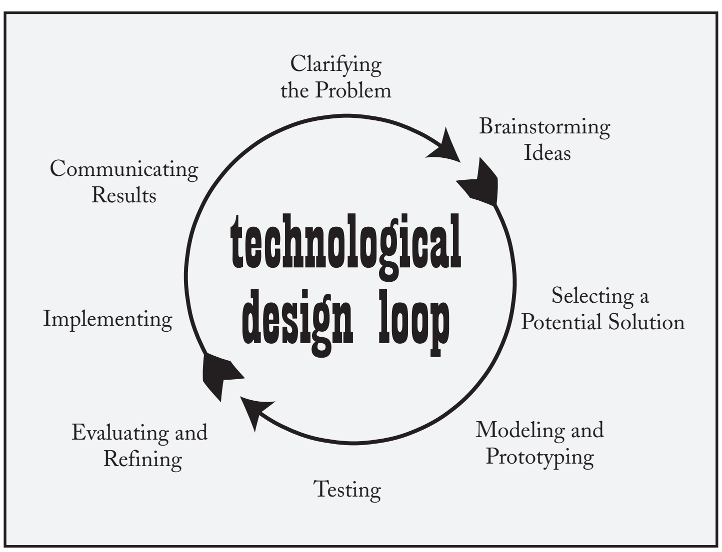


Figure 3. U-shaped structure



Teaching Tips

Technology education focuses substantially on the aspect of design in *Standards for Technological Literacy*. Before constructing anything, students should go through the steps of the design process.

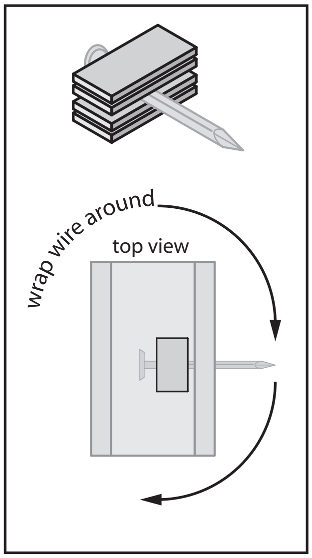
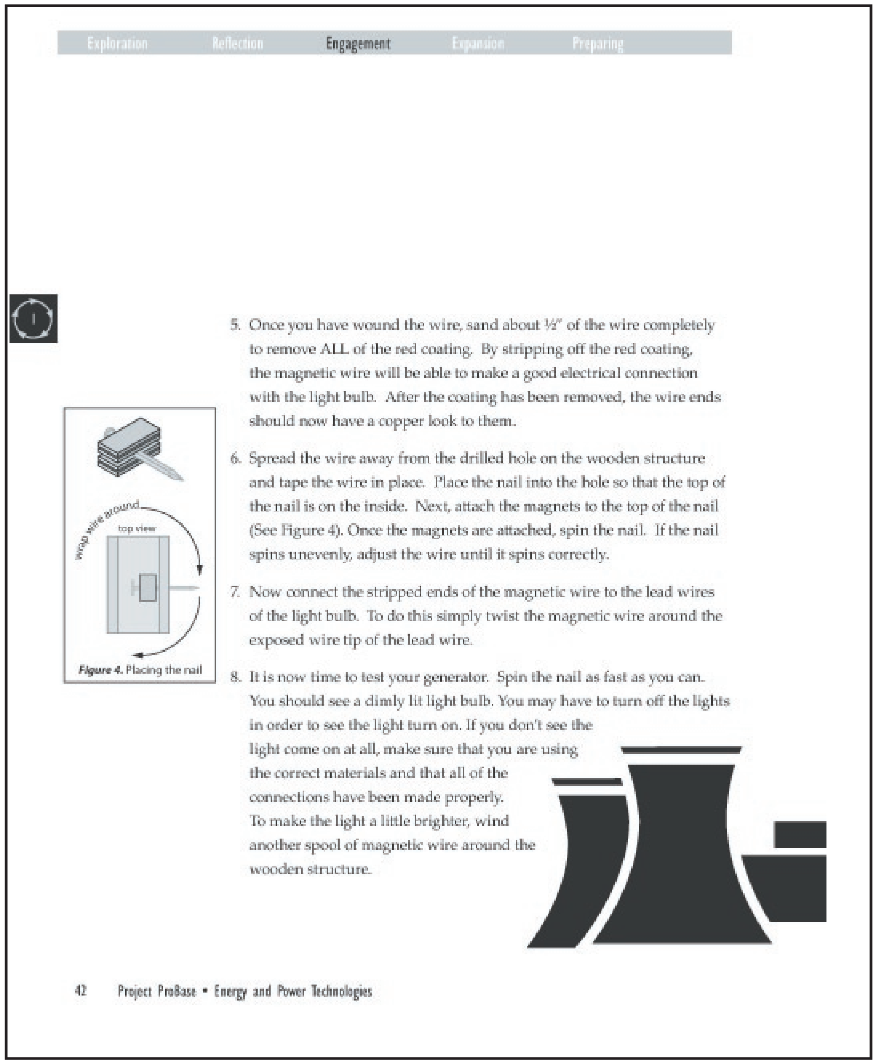


Figure 4. Placing the nail



Exploration Reflection **Engagement** Expansion Preparing

5. Once you have wound the wire, sand about ½" of the wire completely to remove ALL of the red coating. By stripping off the red coating, the magnetic wire will be able to make a good electrical connection with the light bulb. After the coating has been removed, the wire ends should now have a copper look to them.
6. Spread the wire away from the drilled hole on the wooden structure and tape the wire in place. Place the nail into the hole so that the top of the nail is on the inside. Next, attach the magnets to the top of the nail (See Figure 4). Once the magnets are attached, spin the nail. If the nail spins unevenly, adjust the wire until it spins correctly.
7. Now connect the stripped ends of the magnetic wire to the lead wires of the light bulb. To do this simply twist the magnetic wire around the exposed wire tip of the lead wire.
8. It is now time to test your generator. Spin the nail as fast as you can. You should see a dimly lit light bulb. You may have to turn off the lights in order to see the light turn on. If you don't see the light come on at all, make sure that you are using the correct materials and that all of the connections have been made properly. To make the light a little brighter, wind another spool of magnetic wire around the wooden structure.

Figure 4. Placing the nail

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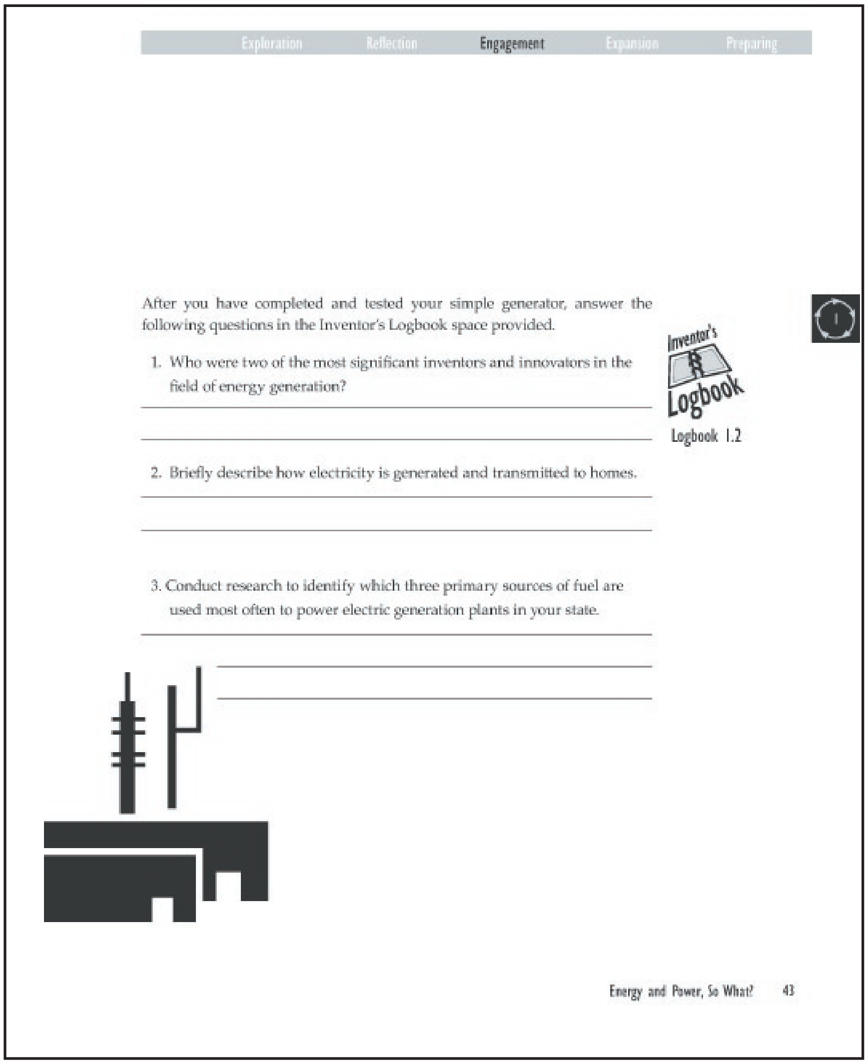


Exploration Reflection Engagement Expansion Preparing

After you have completed and tested your simple generator, answer the following questions in the Inventor's Logbook space provided.

1. Who were two of the most significant inventors and innovators in the field of energy generation?

2. Briefly describe how electricity is generated and transmitted to homes.

3. Conduct research to identify which three primary sources of fuel are used most often to power electric generation plants in your state.

Energy and Power, So What? 43

1. Who were two of the most significant inventors and innovators in the field of energy generation?

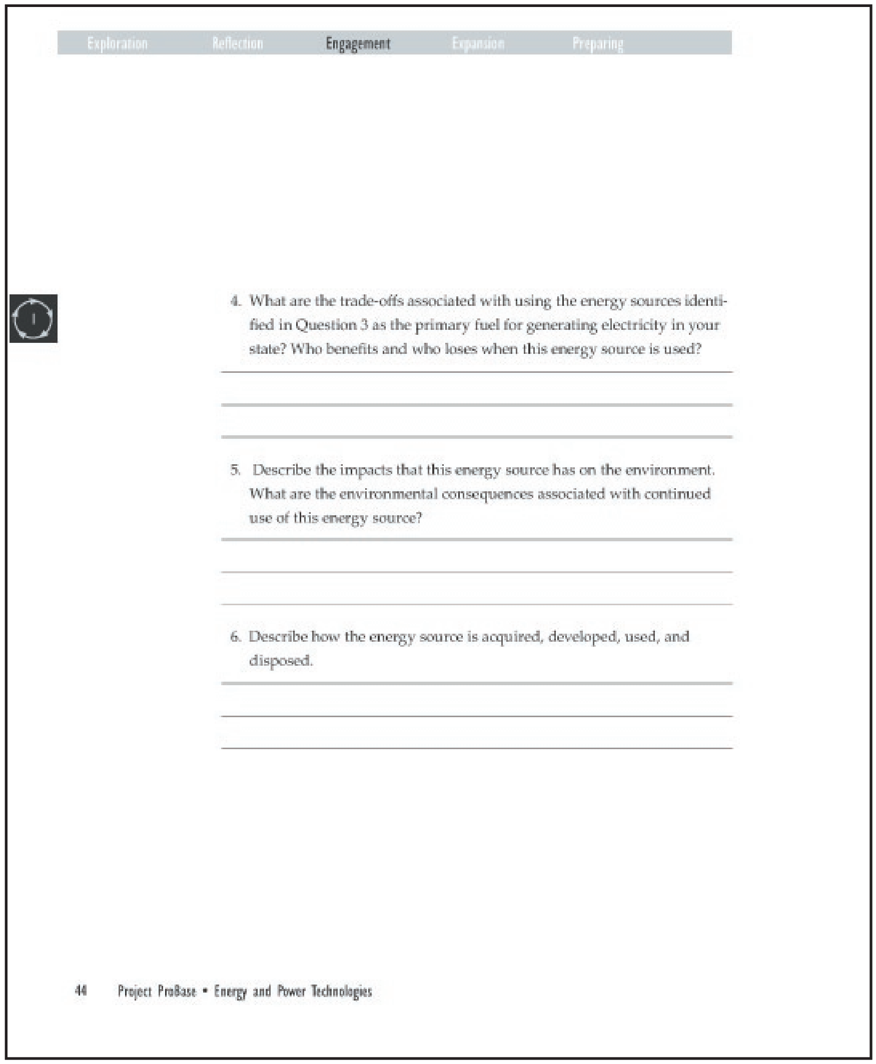
2. Briefly (and in your own words) describe how electricity is generated and transmitted to homes.

3. Conduct research to identify which three primary sources of fuel are used most often to power electric generation plants in your state.

4. What are the trade-offs associated with using these (above) energy sources as the primary fuel for generating electricity in your state? Who benefits and who loses when this energy source is used?

5. Describe the impacts that this energy source has on the environment. What are the environmental consequences associated with continued use of this energy source?

6. Describe how the energy source is acquired, developed, used, and disposed.



Exploration Reflection Engagement Expansion Preparing

4. What are the trade-offs associated with using the energy sources identified in Question 3 as the primary fuel for generating electricity in your state? Who benefits and who loses when this energy source is used?

5. Describe the impacts that this energy source has on the environment. What are the environmental consequences associated with continued use of this energy source?

6. Describe how the energy source is acquired, developed, used, and disposed.

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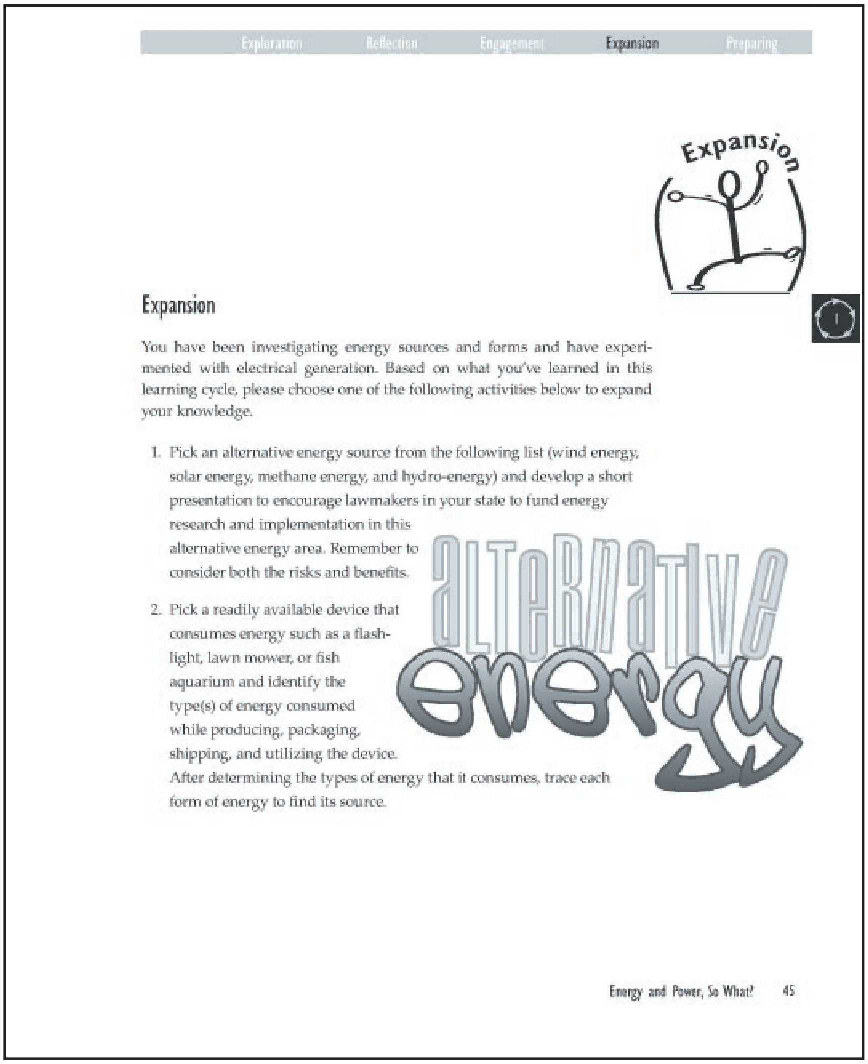


Expansion

You have been investigating energy sources and forms and have experimented with electrical generation. Based on what you've learned in this learning cycle, please choose one of the following activities below to expand your knowledge.

1. Pick an alternative energy source from the following list (wind energy, solar energy, methane energy, and hydro-energy) and develop a short presentation to encourage lawmakers in your state to fund energy research and implementation in this alternative energy area. Remember to consider both the risks and benefits.
2. Pick a readily available device that consumes energy such as a flashlight, lawn mower, or fish aquarium and identify the type(s) of energy consumed while producing, packaging, shipping, and utilizing the device. After determining the types of energy that it consumes, trace each form of energy to find its source.

Expansion

Although not required, the *Expansion* activities are designed to cause teams to delve deeper into the concepts explored in this learning cycle.

1. Pick an alternative energy source from the following list (wind energy, solar energy, methane energy, and hydro-energy) and develop a short presentation that would encourage lawmakers in your state to fund energy research and implementation in this alternative energy area. Remember to consider both the risks and benefits.

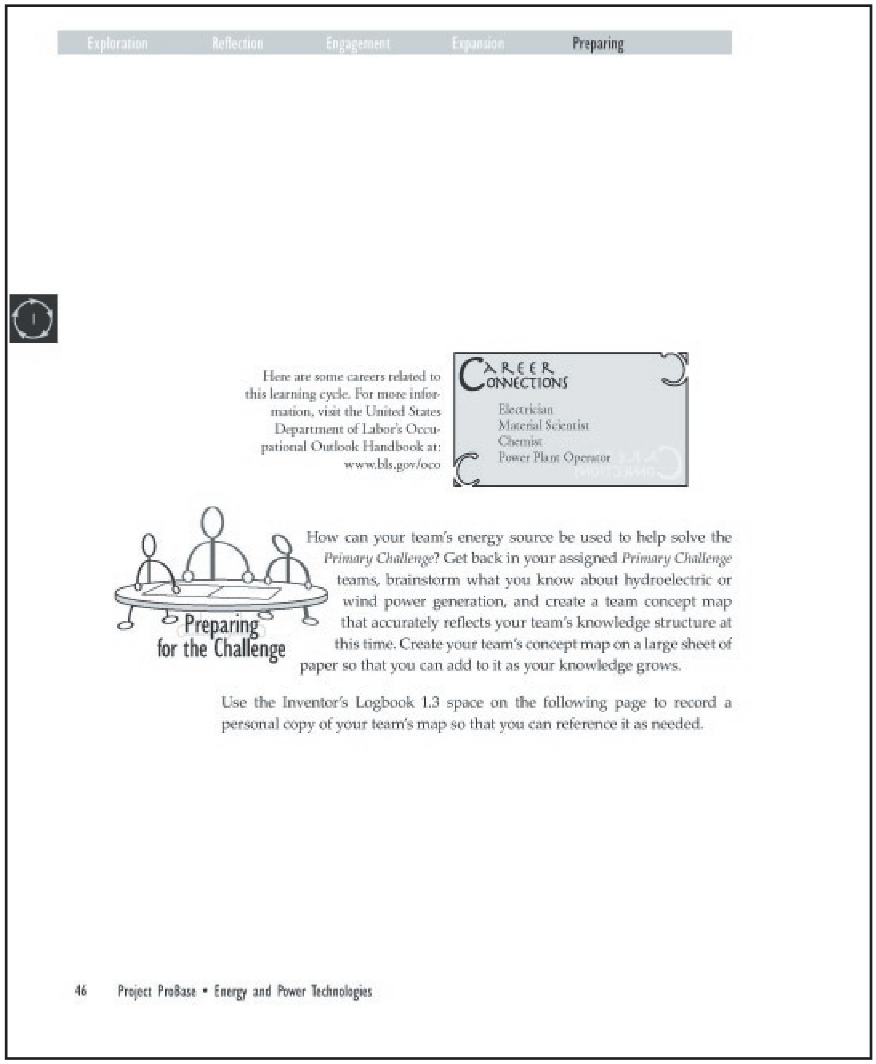
2. Pick a readily available device that consumes energy such as a flashlight, lawn mower, or fish aquarium and identify the type(s) of energy consumed while producing, packaging, shipping, and utilizing the device. After reverse engineering the device to determine the types of energy that it consumes, trace each form of energy to find its source.

Preparing for the Challenge

The sources of energy students learn about in this learning cycle will help them throughout this Learning Unit, which leads to the *Primary Challenge* of building a portable hydroelectric device.

Teaching Tips

Students should work in their *Primary Challenge* teams to create a concept map that accurately reflects their team's knowledge structure related to hydroelectric power. Provide a large sheet of paper for students to create their maps and display the maps in a prominent place in your room so students can refer to them throughout the Learning Unit. Students are provided space in their text to record their team maps.



Exploration Reflection Engagement Expansion **Preparing**

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

CAREER CONNECTIONS

Electrician
Material Scientist
Chemist
Power Plant Operator

Preparing for the Challenge

How can your team's energy source be used to help solve the *Primary Challenge*? Get back in your assigned *Primary Challenge* teams, brainstorm what you know about hydroelectric or wind power generation, and create a team concept map that accurately reflects your team's knowledge structure at this time. Create your team's concept map on a large sheet of paper so that you can add to it as your knowledge grows.

Use the Inventor's Logbook 1.3 space on the following page to record a personal copy of your team's map so that you can reference it as needed.

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Student Assessment

An assessment rubric has been developed for the *Exploration* and *Engagement* activities. Feel free to change this rubric to better suit your particular needs.

Inventor's Logbook

Logbook 1.3

Energy and Power, So What?

Element	Criteria				Points
	4	3	2	1	
Research and Development Timeline Development	Timeline was complete and graphically pleasing.	Timeline was complete,but lacking graphic appeal.	Timeline was not as complete as possible, but graphically pleasing.	Timeline was not complete or graphically appealing.	
Presentation and Communication Preparation	Exceptional preparation of presentation with strong visual aids/handouts/ appropriate technology.	Above average preparation of presentation with good visual aids/handouts/ appropriate technology.	Average preparation of presentation, basic visual aids/handouts/ appropriate technology.	Below average preparation of presentation.	
Effectiveness	Presentation was exceptionally effective, clear, and accurate.	Presentation effectiveness, clarity, and accuracy were about average.	Presentation effectiveness, clarity, and accuracy were average.	Presentation effectiveness, clarity, and accuracy were below average.	
Informative and Interesting	Presentation was exceptionally informative and interesting, with all team members involved.	Presentation was highly informative and interesting, with all team members involved.	Presentation was informative and interesting, with most team members involved.	Presentation was neither informative nor interesting and had little involvement from team members.	
Inventor's Logbook Entries Impacts	Fully identifies the social, environmental, and political impacts of an energy source.	Identifies most of the social, environmental, and political impacts of an energy source.	Identifies a few of the social, environmental, and political impacts of an energy source.	Does not identify the impacts of an energy source.	
Ethical considerations	Fully comprehends ethical considerations.	Comprehends ethical considerations.	Comprehends some ethical considerations.	Does not comprehend ethical considerations.	
				Total Points	

Learning Cycle Two

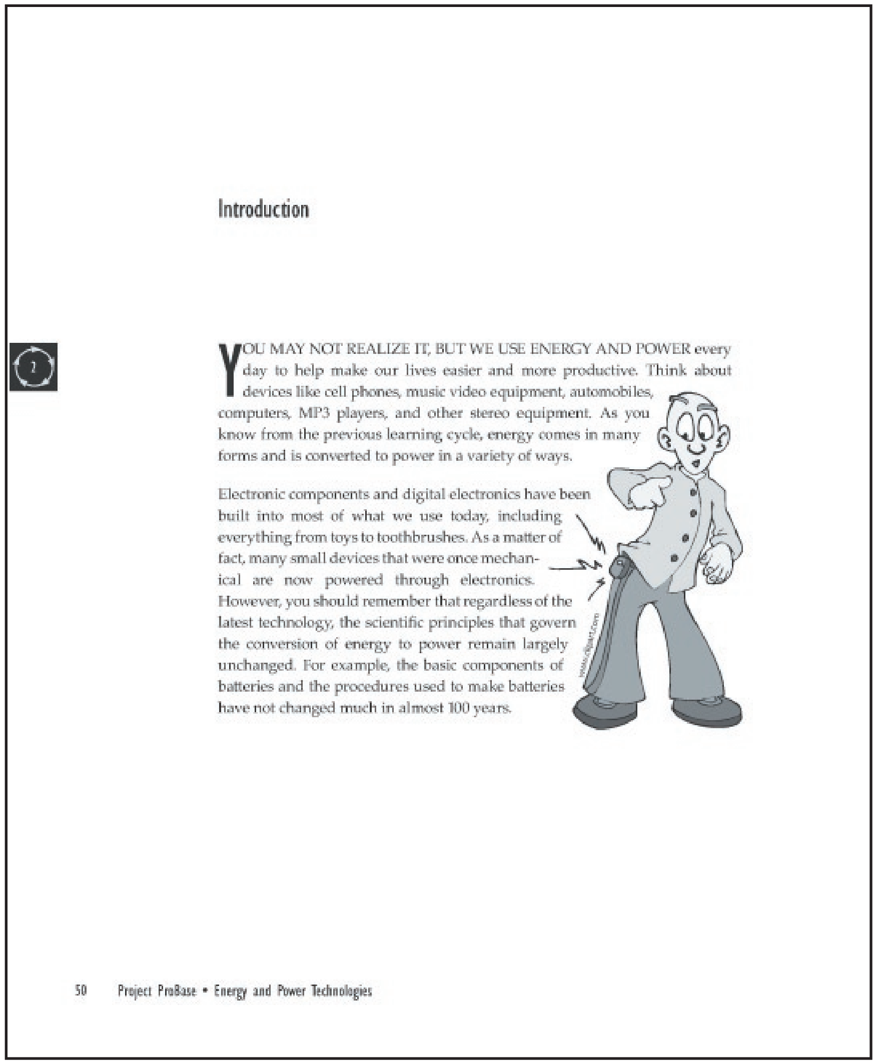
Electronics in Our Lives

Electronics in Our Lives

Introduction

This learning cycle primarily focuses on electronics technology, utilizing simple electronics equipment as the vehicle for learning. Students will be engaged in hands-on activities designed to provide them with a basic introduction to the theory of electricity.

At the beginning of this ten-day learning cycle, students will be presented with a circuit to successfully wire, using a schematic and wiring diagram. As the students progress through the activities, wiring diagrams and directions have been removed from the Student's Guide, which will challenge the students to construct working circuits directly from the schematic diagrams. Despite the fact that students will be constructing rather simple electronic devices, the activities are at a rather high level and will allow students to solve complex problems without using solder and large quantities of consumable components.



Introduction

YOU MAY NOT REALIZE IT, BUT WE USE ENERGY AND POWER every day to help make our lives easier and more productive. Think about devices like cell phones, music video equipment, automobiles, computers, MP3 players, and other stereo equipment. As you know from the previous learning cycle, energy comes in many forms and is converted to power in a variety of ways.

Electronic components and digital electronics have been built into most of what we use today, including everything from toys to toothbrushes. As a matter of fact, many small devices that were once mechanical are now powered through electronics. However, you should remember that regardless of the latest technology, the scientific principles that govern the conversion of energy to power remain largely unchanged. For example, the basic components of batteries and the procedures used to make batteries have not changed much in almost 100 years.

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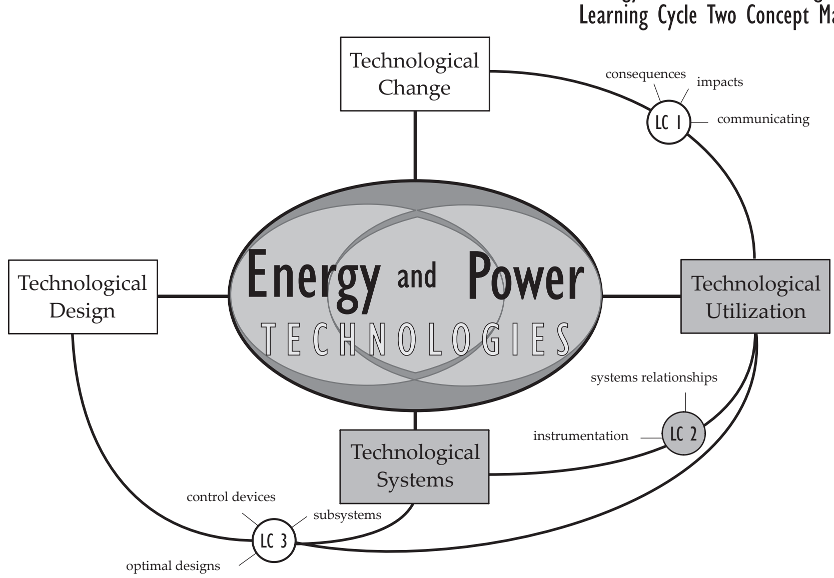
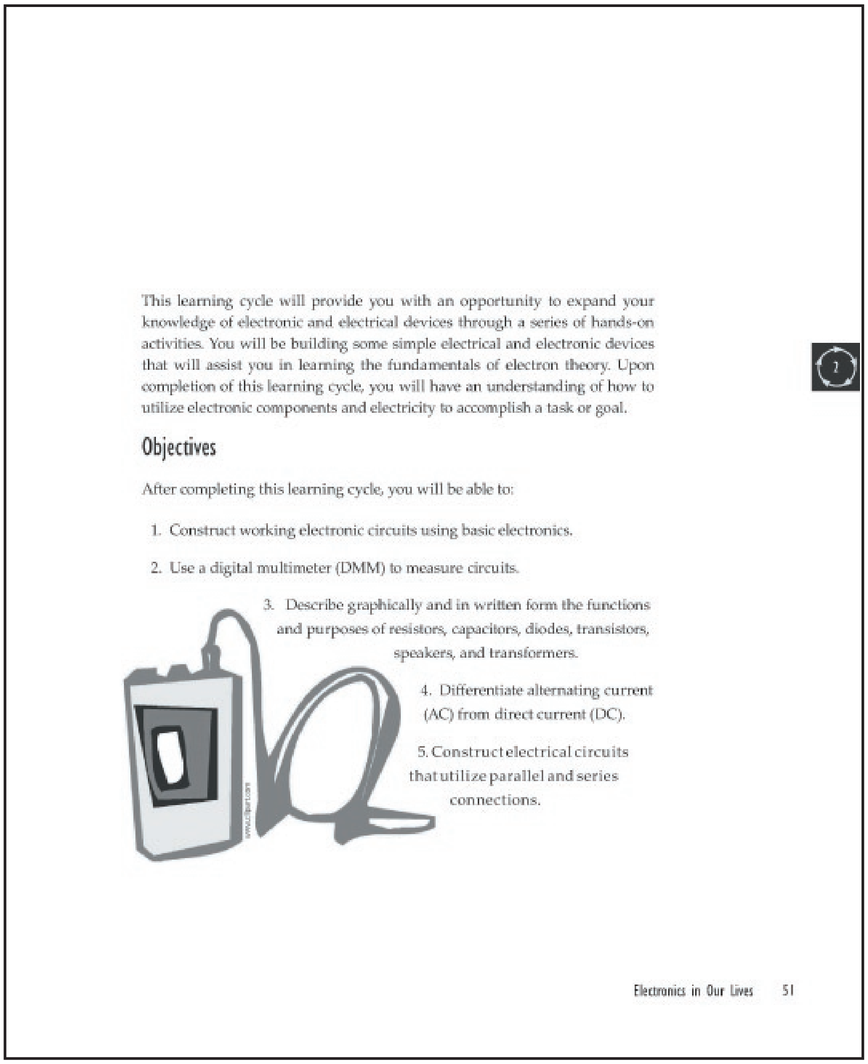
Energy and Power Technologies
Learning Cycle Two Concept Map





This learning cycle will provide you with an opportunity to expand your knowledge of electronic and electrical devices through a series of hands-on activities. You will be building some simple electrical and electronic devices that will assist you in learning the fundamentals of electron theory. Upon completion of this learning cycle, you will have an understanding of how to utilize electronic components and electricity to accomplish a task or goal.

Objectives

After completing this learning cycle, you will be able to:

1. Construct working electronic circuits using basic electronics.
2. Use a digital multimeter (DMM) to measure circuits.
3. Describe graphically and in written form the functions and purposes of resistors, capacitors, diodes, transistors, speakers, and transformers.
4. Differentiate alternating current (AC) from direct current (DC).
5. Construct electrical circuits that utilize parallel and series connections.

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Objectives and Essential Questions

After completing this learning cycle, students will be able to:

1. Construct working electronic circuits.

Essential Question 4b: What are the key elements of the various technological systems and what are the relationships between these systems?

2. Use a digital multimeter (DMM) to measure circuits.

Essential Question 9d: How is technological instrumentation used to measure, calculate, manipulate, and predict the actions of technological devices and systems?

3. Describe graphically and in written form the functions and purposes of resistors, capacitors, diodes, transistors, speakers, and transformers.

Essential Question 4b: What are the key elements of the various technological systems and what are the relationships between these systems?

4. Differentiate alternating current (AC) from direct current (DC).

Essential Question 4b: What are the key elements of the various technological systems and what are the relationships between these systems?

5. Construct electrical circuits that utilize parallel and series connections.

Essential Question 4b: What are the key elements of the various technological systems and what are the relationships between these systems?

Facility Requirements

No special facility requirements are needed as long as students have Internet access and a place to work on their electronic circuits. It would be useful to obtain a number of recycled plastic containers to hold the electronic components while teams are assembling the circuits.

Equipment and Materials

While many of the electronic components can be used over and over, materials are listed by activity below so that you will have a quick reference for each activity.

Based on a class of 28 students:

Each *Exploration* activity:

Button switch

Alligator clips

Jumper wires

Breadboards (7 total)

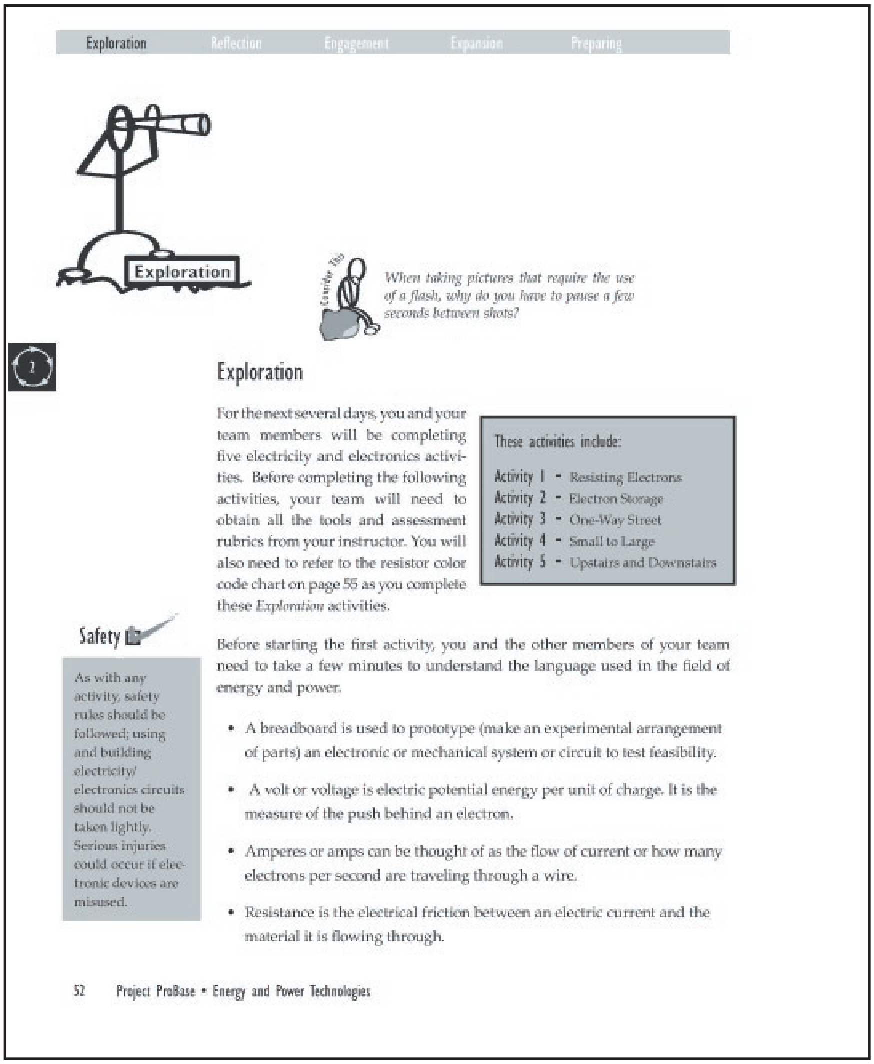
(2) Fresh AA batteries (14 total)

AA battery holders (7 total)

Digital multimeters (DMM) (Any DMM should work. The DMM shown in the student edition is the Radio Shack part #22-805. A good multi-purpose DMM would be the Radio Shack part #22-813.)

Activity 1: Resisting Electrons - 7 each of:

LED
10KΩ resistor
1KΩ resistor
100kΩ resistor



Exploration Reflection Engagement Expansion Preparing

Exploration

When taking pictures that require the use of a flash, why do you have to pause a few seconds between shots?

Exploration

For the next several days, you and your team members will be completing five electricity and electronics activities. Before completing the following activities, your team will need to obtain all the tools and assessment rubrics from your instructor. You will also need to refer to the resistor color code chart on page 55 as you complete these *Exploration* activities.

These activities include:

Activity 1 - Resisting Electrons
Activity 2 - Electron Storage
Activity 3 - One-Way Street
Activity 4 - Small to Large
Activity 5 - Upstairs and Downstairs

Safety

As with any activity, safety rules should be followed; using and building electricity/electronics circuits should not be taken lightly. Serious injuries could occur if electronic devices are misused.

Before starting the first activity, you and the other members of your team need to take a few minutes to understand the language used in the field of energy and power.

- A breadboard is used to prototype (make an experimental arrangement of parts) an electronic or mechanical system or circuit to test feasibility.
- A volt or voltage is electric potential energy per unit of charge. It is the measure of the push behind an electron.
- Amperes or amps can be thought of as the flow of current or how many electrons per second are traveling through a wire.
- Resistance is the electrical friction between an electric current and the material it is flowing through.

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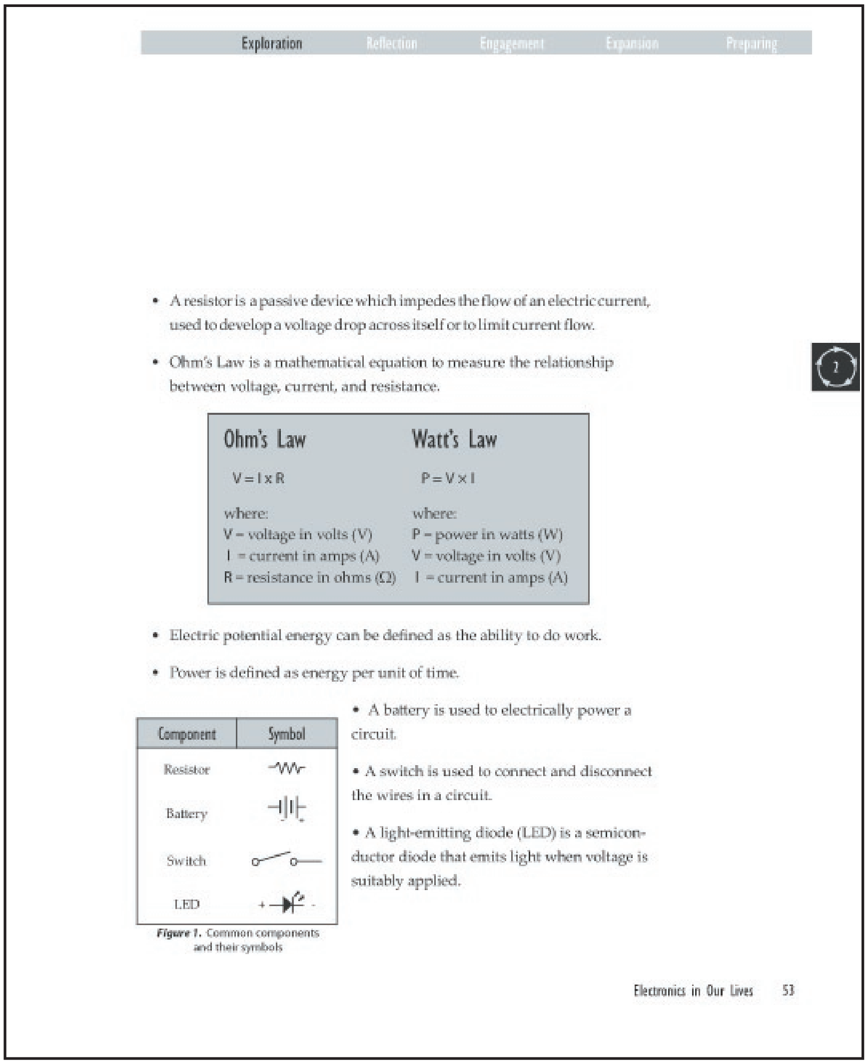
Activity 2: Electron Storage - 7 each of:

LED
10KΩ resistor
3.3KΩ resistor
1kΩ resistor
100µF capacitor
10µF capacitor

Activity 3: One-Way Street - 7 each of:

Red LED
Green LED
Diode
3.3KΩ resistor
100µF capacitor



Exploration Reflection Engagement Expansion Preparing

- A resistor is a passive device which impedes the flow of an electric current, used to develop a voltage drop across itself or to limit current flow.
- Ohm's Law is a mathematical equation to measure the relationship between voltage, current, and resistance.

Ohm's Law	Watt's Law
$V = I \times R$	$P = V \times I$
where: V = voltage in volts (V) I = current in amps (A) R = resistance in ohms (Ω)	where: P = power in watts (W) V = voltage in volts (V) I = current in amps (A)

- Electric potential energy can be defined as the ability to do work.
- Power is defined as energy per unit of time.

Component	Symbol
Resistor	
Battery	
Switch	
LED	+ -

Figure 1. Common components and their symbols

- A battery is used to electrically power a circuit.
- A switch is used to connect and disconnect the wires in a circuit.
- A light-emitting diode (LED) is a semiconductor diode that emits light when voltage is suitably applied.

Electronics in Our Lives 53

Suggested Daily Outline

Day One	Day Two
Introduction *Exploration* Activity 1	*Exploration* Activity 2
Day Three	**Day Four**
Exploration Activity 3	*Exploration* Activity 4
Day Five	**Day Six**
Exploration Activity 5	*Exploration* Activity 6
Day Seven	**Day Eight**
Reflection, Discussion	*Engagement*
Day Nine	**Day Ten**
Engagement	*Engagement*
Day Eleven	
Preparing for the Challenge	

Estimated number of 50-minute class periods: **11**

Activity 4: Small to Large - 7 each of:

- LED
- 3.3KΩ resistor
- 100KΩ resistor
- 470Ω resistor
- 100μF capacitor
- NPN transistor

Activity 5: Upstairs and Downstairs - 7 each of:

- Red LED
- Green LED
- 1MΩ resistor
- 100KΩ resistor
- 10KΩ resistor
- 100μF capacitor
- NPN transistor

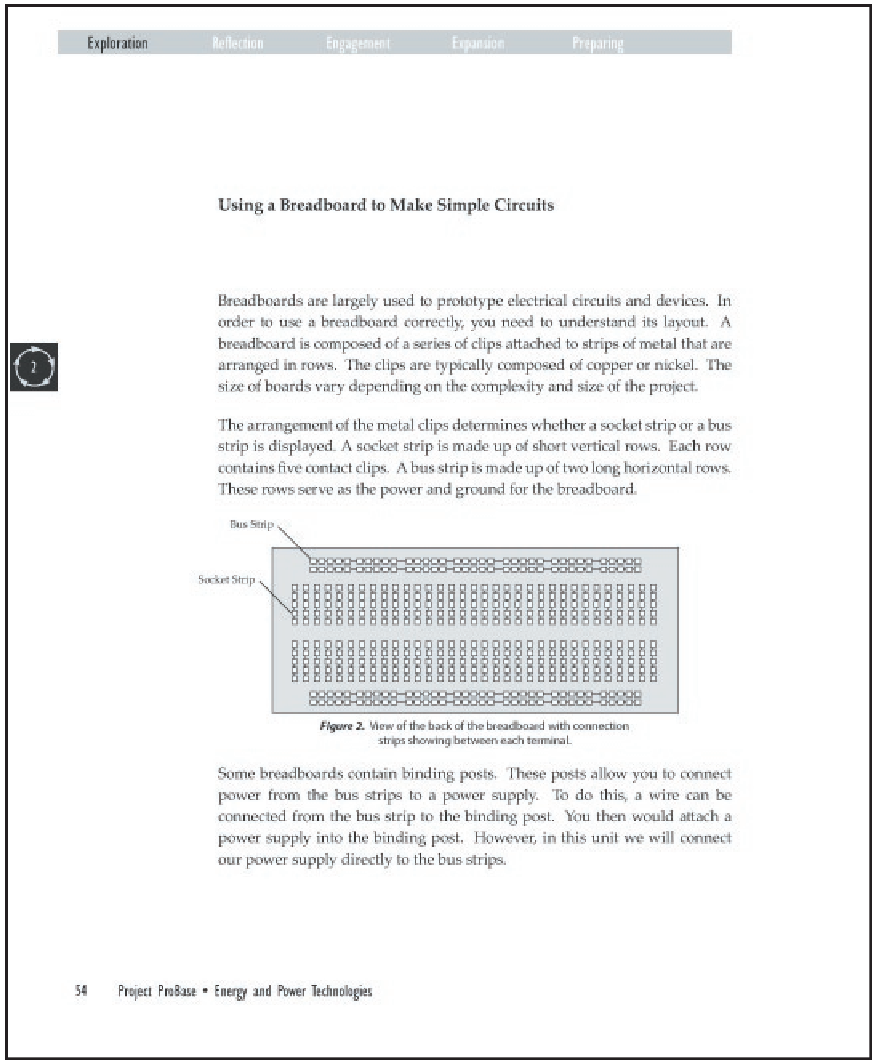
Engagement

- .0047 μF capacitor
- 1 M resistor
- 3.3 K resistor
- NPN transistor
- Transformer
- Piezo speaker
- Breadboard
- 2 AA batteries
- AA battery holder

Exploration

For ten days, students should work in teams (as assigned by you) to conduct the five activities. You may choose to have all teams working on the same activity at the same time or you may choose to have different teams start with different activities. However, you should note that the first two activities include more specific instructions for the students. As the teams progress towards Activity 5, students will find that the difficulty level has increased.

Students may need assistance with their circuits. Since you will have photographs of completed circuits in the Instructor's Guide, you may want to refer to these photos and accompanying diagrams when answering student questions. You are encouraged to resist the tendency to provide answers too quickly. Rather, encourage students to think through the problems that they encounter before providing answers.


Exploration Reflection Engagement Expansion Preparing

Using a Breadboard to Make Simple Circuits

Breadboards are largely used to prototype electrical circuits and devices. In order to use a breadboard correctly, you need to understand its layout. A breadboard is composed of a series of clips attached to strips of metal that are arranged in rows. The clips are typically composed of copper or nickel. The size of boards vary depending on the complexity and size of the project.

The arrangement of the metal clips determines whether a socket strip or a bus strip is displayed. A socket strip is made up of short vertical rows. Each row contains five contact clips. A bus strip is made up of two long horizontal rows. These rows serve as the power and ground for the breadboard.

Figure 2. View of the back of the breadboard with connection strips showing between each terminal.

Some breadboards contain binding posts. These posts allow you to connect power from the bus strips to a power supply. To do this, a wire can be connected from the bus strip to the binding post. You then would attach a power supply into the binding post. However, in this unit we will connect our power supply directly to the bus strips.

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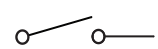
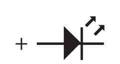
Component	Symbol
Resistor	
Battery	
Switch	
LED	

Figure 1. Common components and their symbols

Exploration | Reflection | Engagement | Expansion | Preparing

Resistor Color Code Chart

The most common type of component used in electronics is the resistor. Resistors are used in virtually all electrical and electronic circuits. The color coding used for marking resistors is as follows. Each color represents a number, (0) zero through (9) nine, as indicated in the chart below. Note that one color band is very close to the edge of the resistor. Orient the resistor so that this band is at the left. This is the "first significant digit." The second band is the "second significant digit." The third band is the "multiplier." The color of the multiplier band indicates how many zeros are to be placed after the first two digits (e.g., Black-Black-Brown = 100 ohms). The fourth color band (if there is one) is a metallic color, either silver or gold. In the fourth color band position, silver represents 10% tolerance and gold represents 5% tolerance. No fourth band indicates 20% tolerance. *NOTE: if a resistor has a 10% tolerance, that means that the actual resistance can be as much as 10% above or below the resistance indicated by the color code.*

Color	Band 1 1st	Band 2 2nd	Band 3 Multiplier	Band 4 Tolerance
Black	0	0	None	
Brown	1	1	0	
Red	2	2	00	
Orange	3	3	000	
Yellow	4	4	0,000	
Green	5	5	00,000	
Blue	6	6	000,000	
Violet	7	7	0,000,000	
Grey	8	8	00,000,000	
White	9	9	000,000,000	
Gold			0.1	5%
Silver			0.01	10%
None				20%

If a metallic band, either silver or gold, appears in the "third significant digit", or multiplier position, it is a Fractional Multiplier (e.g. gold-multiply by 0.1; silver-multiply by 0.01)

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2

Safety

As with any activity, safety rules should be followed. Using and building electricity/electronics circuits should not be taken lightly. Serious injuries could occur if electronic devices are misused.

Activity One – Resisting Electrons

Resistors

Key Terms

Resistor:
A device that limits the flow of electric current in a circuit; measured in ohms (Ω)

On a basic level, a resistor simply slows down the flow of current in any circuit. A higher value resistor will constrict the flow more than a lower numeric resistor. Below is an example that shows how the resistor color code chart (on the previous page) can be used to figure out a resistor's value with color bands of yellow, violet, and brown.

- First stripe is yellow, which means the left-most digit is a 4.
- Second stripe is violet, which means the next digit is a 7.
- Third stripe is brown. Since brown is 1, it means add one zero to the right of the first two digits.

Yellow-Violet-Brown = 4-7-0

Use the resistor color code chart as a reference to identify resistors. The color variations of this chart can be found through a simple search on the Internet.

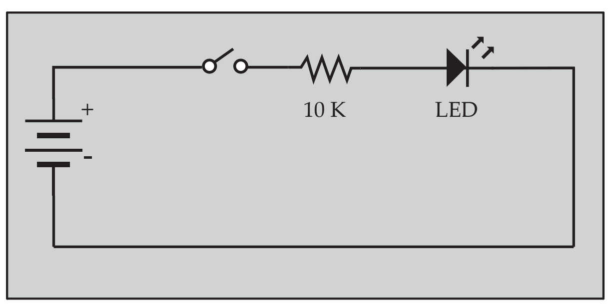


Figure 3

Activity One – Resisting Electrons

Your team should gather the following materials before beginning this activity:

Breadboard	Button switch
LED	Alligator clips
10KΩ resistor	Jumper wires
1KΩ resistor	(2) AA batteries
100kΩ resistor	AA battery holder

Gather the necessary materials from your instructor and follow the steps outlined below to build the circuit and complete the experiments. (Be careful not to drop or lose any of the components. Electronic components are very fragile.)

Building the circuit

During Activity 1, you will discover the importance and value of resistors.

1. Review the section on breadboards and resistors.
2. Examine the schematic diagram in Figure 3 carefully before working with the breadboard.
3. To begin building the circuit on the breadboard, find the positive leg of the LED. The positive leg is always the longer leg on the LED. This is important because the LED will not operate if installed incorrectly.

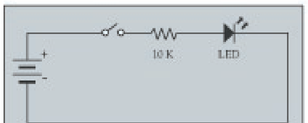
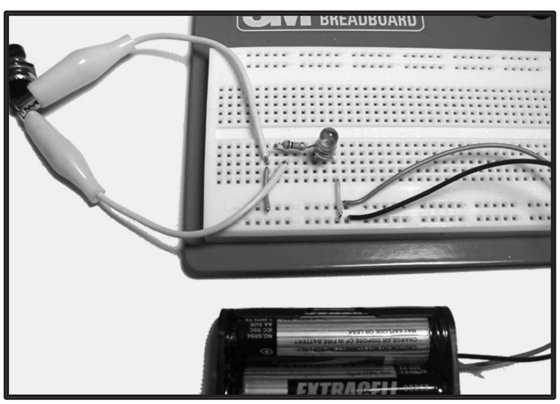


Figure 3.



4. Place the LED in the breadboard so that one leg of the LED is in one row and the other is in a different row. Refer to the review section on breadboards if you do not understand the reference to "rows" in the instructions above.

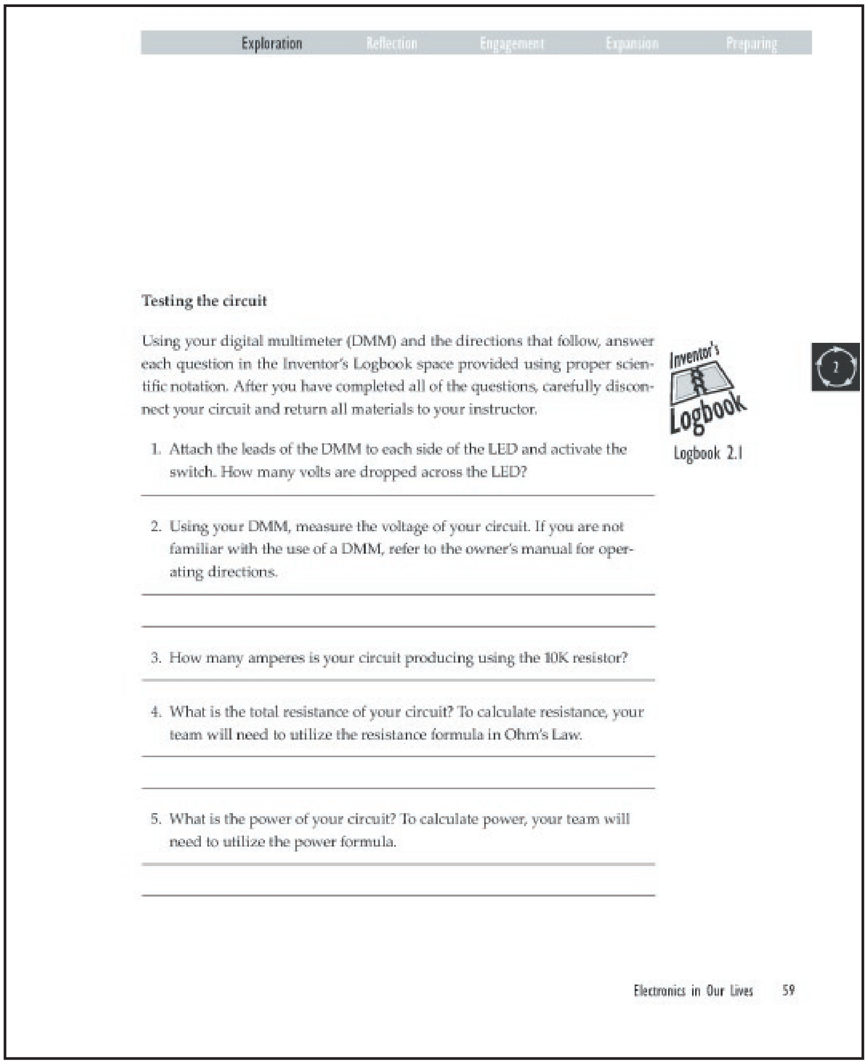
5. Next, attach one leg of the 10k Ω resistor in the same row as the positive leg of the LED. Place the other leg in an empty row. These components are now connected in series. A further discussion of series circuits will occur later in this learning cycle.

6. Now, attach the button switch in series with the resistor (one leg in the same row as the resistor and one in an empty row). After you have completed this, you need to attach a jumper wire (a short length of wire) from the negative leg of the LED to the ground row (the sideways row farthest from the center of the board). Also, attach a jumper wire from the push switch to the positive power row (the sideways row closest to the center of the board; see Figure 2 on page 54).

7. Now, put the ground end (black wire) of the power source in the ground row (the sideways row farthest from the center of the board). Next, put the positive end (red wire) of the power source in the positive power row (the sideways row closest to the center of the board).

8. Your instructor needs to check your circuit before pushing the switch.

9. Push the switch to turn the light on and off.



Exploration Reflection Engagement Expansion Preparing

Testing the circuit

Using your digital multimeter (DMM) and the directions that follow, answer each question in the Inventor's Logbook space provided using proper scientific notation. After you have completed all of the questions, carefully disconnect your circuit and return all materials to your instructor.

Inventor's Logbook

Logbook 2.1

1. Attach the leads of the DMM to each side of the LED and activate the switch. How many volts are dropped across the LED?
2. Using your DMM, measure the voltage of your circuit. If you are not familiar with the use of a DMM, refer to the owner's manual for operating directions.
3. How many amperes is your circuit producing using the 10K resistor?
4. What is the total resistance of your circuit? To calculate resistance, your team will need to utilize the resistance formula in Ohm's Law.
5. What is the power of your circuit? To calculate power, your team will need to utilize the power formula.

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Students are asked to respond to the following questions:

1. Attach the leads of the DMM to each side of the LED and activate the switch. How many volts are dropped across the LED?
2. Using your DMM, measure the voltage of your circuit. If you are not familiar with the use of a DMM, refer to the owner's manual for operating directions.
3. How many amperes is your circuit producing using the 10K resistor?
4. What is the total resistance of your circuit? To calculate resistance, your team will need to utilize the resistance formula in Ohm's Law.
5. What is the power of your circuit? To calculate power, your team will need to utilize the power formula.

6. Remove the 10K resistor and rewire the circuit using the 1K resistor. Compared to the first resistor (10K), what did you observe about the LED when the switch was pressed? Explain your observation of the circuit.

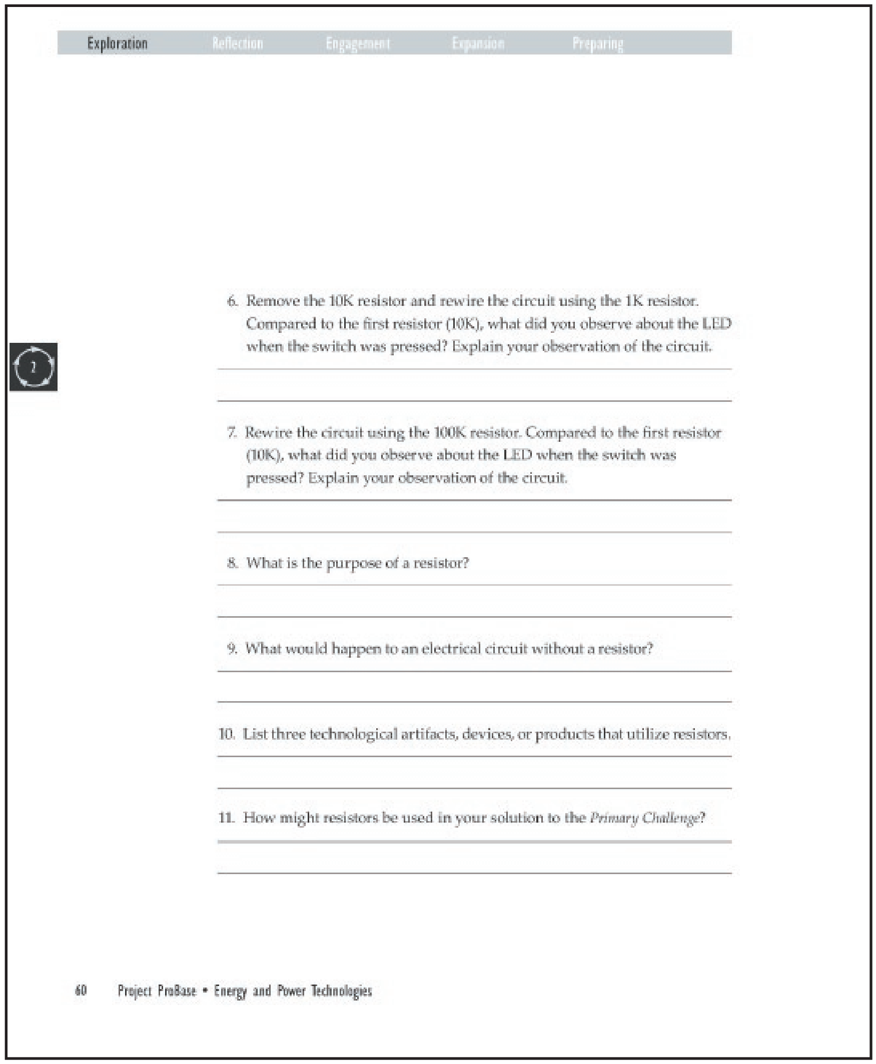
7. Rewire the circuit using the 100K resistor. Compared to the first resistor (10K), what did you observe about the LED when the switch was pressed? Explain your observation of the circuit.

8. What is the purpose of a resistor?

9. What would happen to an electrical circuit without a resistor?

10. List three technological artifacts, devices, or products that utilize resistors.

11. How might resistors be used in your solution to the *Primary Challenge*?



Exploration Reflection Engagement Expansion Preparing

6. Remove the 10K resistor and rewire the circuit using the 1K resistor. Compared to the first resistor (10K), what did you observe about the LED when the switch was pressed? Explain your observation of the circuit.

7. Rewire the circuit using the 100K resistor. Compared to the first resistor (10K), what did you observe about the LED when the switch was pressed? Explain your observation of the circuit.

8. What is the purpose of a resistor?

9. What would happen to an electrical circuit without a resistor?

10. List three technological artifacts, devices, or products that utilize resistors.

11. How might resistors be used in your solution to the *Primary Challenge*?

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Capacitors

As the definition states, a capacitor is a device used to store electricity. A simple capacitor consists of three parts: two metal plates and a dialectric in between. A dialectric is anything that does not conduct electricity, such as paper or plastic. Each metal plate is connected to a terminal, one positive and one negative.

Key Terms

Capacitor: A device used to store electricity; measured in farads

When correctly connected to a power supply, an electrical charge will flow into the capacitor and stay there until released. Charging a capacitor occurs when a voltage difference is present between two conductors that are close together, but electrically insulated from each other. Charging or storing electrons in a capacitor occurs until the voltage difference is equal to the applied voltage. For example, if 10 volts are applied to a capacitor, the capacitor will charge up to 10 volts, but no more than that.

Depending upon the quality of the capacitor, the volts charged will remain intact until they are discharged by another device. The amount of voltage a capacitor can hold depends on the size of the metal plates, the distance between them, and the material of the dialectric.

Capacitance (the ability to hold the charge) is dependent upon the size of the capacitor. Capacitors are very useful in any circuit where a charge must be stored and released. Capacitors have several uses. One is to remove waves and level out the flow of electrons in a circuit. Another is to store energy for a large-volume use (such as in a camera flash). A third use is to block DC voltage and allow the passage of AC.

Notes:

Notes:

Reading a Capacitor

Identifying the value of capacitors is not always clear. Instead of using bands, capacitors have numbers written on one side. This section will help you understand the basics of identifying some capacitors.

Capacitor general helpful hints:

Two-digit whole numbers ***usually*** indicate nanofarads.

Decimal numbers ***usually*** indicate microfarads.

Three-digit whole numbers ***usually*** indicate picofarads.

Tolerance Codes	
Letter	Tolerance (+/-)
M	20%
K	10 %
J	5 %
H	2.5 %
F	1 %

Table 1. Tolerance codes; not all-inclusive

Typical capacitors can display several pieces of information: capacitance value, tolerance (as shown in Table 1), voltage, and temperature coefficients. For an idea of how this information appears on a capacitor, see Figure 4.

Small capacitors are usually labeled in µ (micro-Farads), n (nano-Farads), or pF (pico-Farads). Using the example in Figure 5 on the next page, the capacitor has a value of .01 µF (micro-Farads) (± 10%) at 50 working volts.

Remember: Since there is no standard method for labeling a capacitor, the best method to determine capacitance is by using a meter.

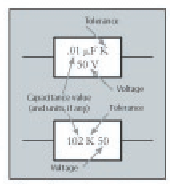


Figure 4. Locating values on a capacitor

If there is neither a µ nor n, then the value of the capacitor is usually stated in pF (pico-Farads) (see Figure 6 on the next page). Often, when the specified capacitance is small, it is stated in µF *(micro-Farads)*, which must be converted to pF or nF to match the formatting of the value stamped on the capacitor. For example, 0.01 µF is equivalent to 100,000 pF and would be stamped as 104 on the capacitor.

Figure 5. Example capacitor labeled in µF

Figure 6. Example capacitor labeled in pF

Figure 7. Determine the value of this capacitor: __________ µF

Inventor's Logbook

Logbook 2.2

When determining the value of a capacitor, as in Figure 5, the first two numbers (1 and 0) are placeholders and the third number (2) is the multiplier (how many zeros you add to the end). In this case, the capacitance is 10 pF $\times 10^2$ or 1000 pF. This number is the same as 1.0 nF or .001 µF *(± 10%) at 50 working volts.*

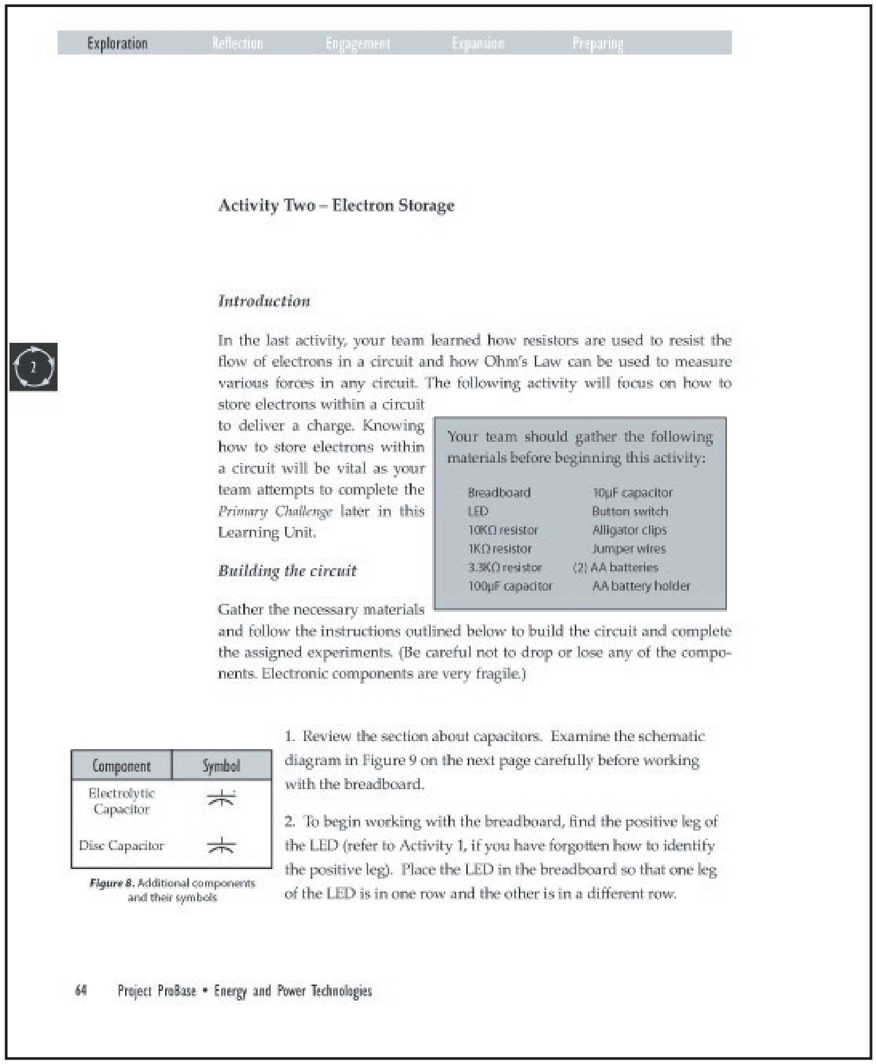
Determine the value of the capacitor in Figure 7 on your own.

Converting Capacitance				
Unit	Abbrev.	Multiplier	Symbol on capacitor	Example
micro-farad	µF	10^{-6} F	µF	0.3 µF
nano-farad	nF	10^{-9} F	n	300 nF
picofarad	pF	10^{-12} F	none	300,000 pF

Table 2. Converting capacitance

Notes:

Activity Two – Electron Storage



Activity Two – Electron Storage

Introduction

In the last activity, your team learned how resistors are used to resist the flow of electrons in a circuit and how Ohm's Law can be used to measure various forces in any circuit. The following activity will focus on how to store electrons within a circuit to deliver a charge. Knowing how to store electrons within a circuit will be vital as your team attempts to complete the *Primary Challenge* later in this Learning Unit.

Your team should gather the following materials before beginning this activity:

Breadboard	10μF capacitor
LED	Button switch
10KΩ resistor	Alligator clips
1KΩ resistor	Jumper wires
3.3KΩ resistor	(2) AA batteries
100μF capacitor	AA battery holder

Building the circuit

Gather the necessary materials and follow the instructions outlined below to build the circuit and complete the assigned experiments. (Be careful not to drop or lose any of the components. Electronic components are very fragile.)

Component	Symbol
Electrolytic Capacitor	
Disc Capacitor	

Figure 8. Additional components and their symbols

1. Review the section about capacitors. Examine the schematic diagram in Figure 9 on the next page carefully before working with the breadboard.

2. To begin working with the breadboard, find the positive leg of the LED (refer to Activity 1, if you have forgotten how to identify the positive leg). Place the LED in the breadboard so that one leg of the LED is in one row and the other is in a different row.

Component	Symbol
Electrolytic Capacitor	
Disc Capacitor	

Figure 8. Additional components and their symbols

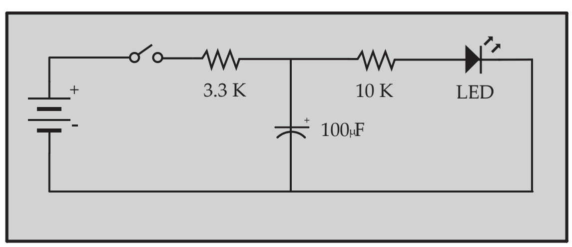


Figure 9.

3. Then attach the 3.3K Ω resistor in series with the LED. To do this, attach one leg of the 3.3K Ω resistor in the same row as the positive leg of the LED. Place the other leg in an empty row. Next, attach the 10K Ω resistor in series with the 3.3K Ω resistor. After attaching both resistors, attach the push button in series with the 10K Ω resistor.

4. Now, take the positive leg of the 100µF capacitor (the legs of the capacitor should be marked) and attach it in the same row the 3.3KΩ resistor leg and the 10KΩ resistor leg share. Now, take the negative leg of the 100µF capacitor and attach it to the ground row. The capacitor is now in parallel.

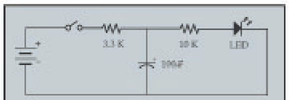


Figure 9.

5. Next, attach a jumper wire from the negative leg of the LED to the ground row. Take another jumper wire and attach it from the switch to the positive row. Now, put the ground end of the power source in the ground row. Then put the positive end of the power source in the positive power row.

6. Your instructor needs to check your circuit before pushing the switch.

7. Push the switch on and off.

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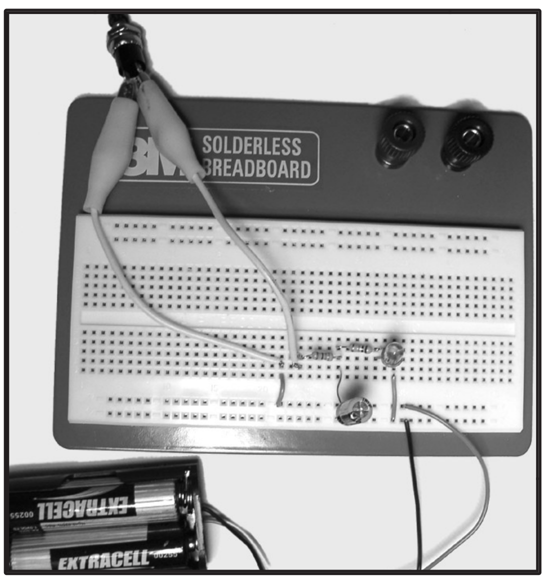
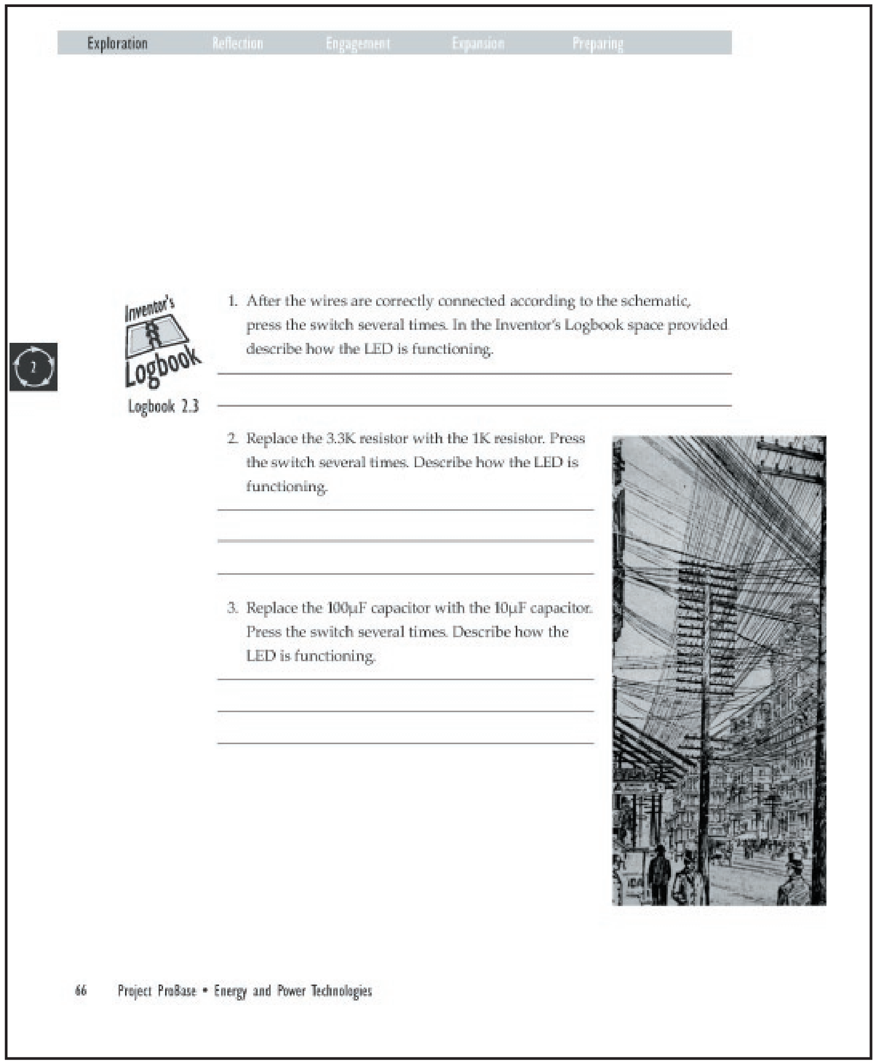


Students are asked to respond to the following questions:

1. After the wires are correctly connected according to the schematic for the circuit (see Figure 9), press the switch several times. In the Inventor's Logbook space provided describe how the LED is functioning.

2. Replace the 3.3K resistor with the 1K resistor. Press the switch several times. In the Inventor's Logbook space provided, describe how the LED is functioning.

3. Replace the 100µF capacitor with the 10µF capacitor. Press the switch several times. In the Inventor's Logbook space provided, describe how the LED is functioning.



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Inventor's Logbook

Logbook 2.3

1. After the wires are correctly connected according to the schematic, press the switch several times. In the Inventor's Logbook space provided describe how the LED is functioning.

2. Replace the 3.3K resistor with the 1K resistor. Press the switch several times. Describe how the LED is functioning.

3. Replace the 100µF capacitor with the 10µF capacitor. Press the switch several times. Describe how the LED is functioning.

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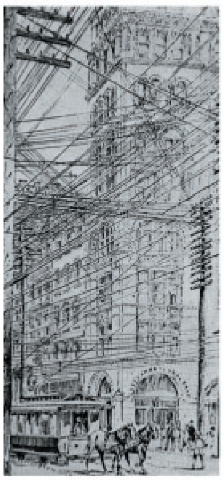
4. Excluding the examples provided in the student guide, list three technological products, devices, or artifacts that utilize capacitors. What is the purpose of the capacitor in these devices?



5. At this point of learning cycle two, your team has not been exposed to the "understanding" of series or parallel circuits. However, based on this activity, you wired the resistors in series. What does *series* mean? What does *parallel* mean? Conduct an Internet search to find sites that explain how a series and parallel circuit works. Successful search terms include "series circuits," "parallel circuits," and "electrical circuits."

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4. Excluding the examples provided in the student guide, list three technological products, devices, or artifacts that utilize capacitors. What is the purpose of the capacitor in these devices?

5. At this point in Learning Cycle Two, your team has not been exposed to the "understanding" of series or parallel circuits. However, based on this activity, you wired the resistors in series. What does *series* mean? What does *parallel* mean? Conduct an Internet search to find sites that explain how series and parallel circuits work. Successful search terms include "series circuits," "parallel circuits," and "electrical circuits."

2

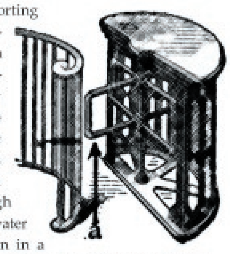
Notes:

Activity Three – One-Way Street

Introduction

In the last activity, your team learned how resistors and capacitors work together to store electrons. In this activity, you will learn how diodes work, their purposes, and how they function with other technological artifacts, devices, or products.

Diodes



When was the last time you went to a sporting event where you had to walk through a turnstile? Why does a bicycle tire let air go in but not out? Answers to both of these questions will help you better understand how a diode works. Turnstiles allow people to walk through, but they don't allow people to reverse direction. Bicycle tire air valves and water sump pump check valves work in much the same way. They push water through a check valve, which does not allow the water or air to reverse direction. Diodes function in a similar manner. Diodes (also known as rectifiers) are semiconductor electronic devices that allow an electrical current to flow in only one direction. A diode can also be used for converting AC power to DC power.

2

Activity Three – One-Way Street

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Using the Internet, search for information on how semiconductors, diodes, and light-emitting diodes work. Use appropriate keywords in your search such as "electronic components," "conductors," "diodes," "light-emitting diodes," and "LED."

In you own words, explain how semiconductors, diodes, and light-emitting diodes work and the purpose of each. Record your answer in the Inventor's Logbook space provided.

Inventor's Logbook

Logbook 2.4

Your team should gather the following materials before beginning this activity:

Breadboard	Button switch
Red LED	Alligator clips
Green LED	Jumper wires
Diode	(2) AA batteries
3.3KΩ resistor	AA battery holder
100µF capacitor	

Gather the necessary materials and follow the instructions on the next pages to build the circuit and complete experiments with what you have constructed. *(Be careful not to drop or lose any of the components. Electronic components are very fragile and easily misplaced).*

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Notes:

Building the 1st Circuit

1. Examine the schematic diagram in Figure 10 carefully before working with the breadboards.
2. Find the positive leg to the LED first. Place the LED in the breadboard so that one leg of the LED is in one row and the other is in a different row.

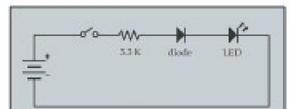


Figure 10.

3. Next find the negative leg of the diode. The negative leg is the side closest to the line on the component. Attach the negative leg of the diode in the same row as the positive leg of the LED. Place the other leg in an empty row. (These components are now in series.)
4. Then attach the 3.3K Ω resistor in series with the diode. Next, attach the push button in series with the resistor. After you have completed this, you need to attach a jumper wire from the switch to the positive power row. Also, attach a jumper wire from the negative leg of the LED to the ground row.

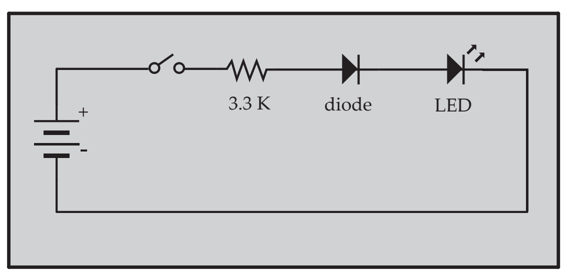
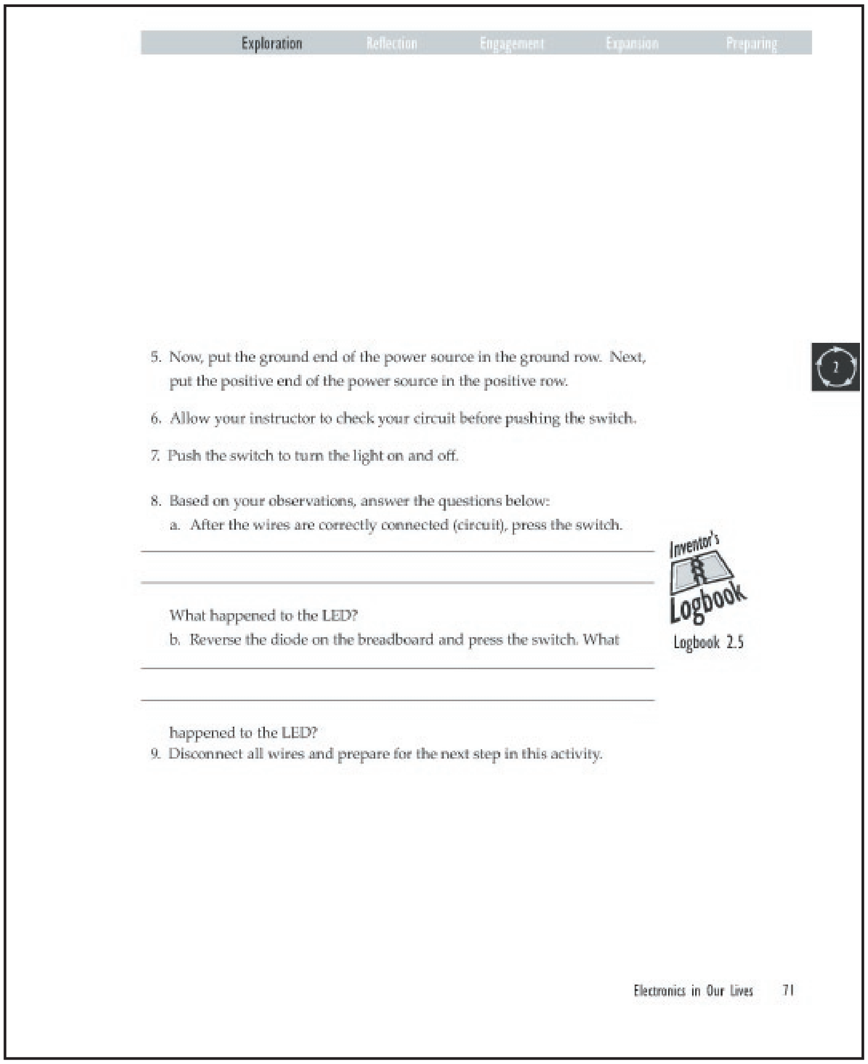


Figure 10.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5. Now, put the ground end of the power source in the ground row. Next, put the positive end of the power source in the positive row.
6. Allow your instructor to check your circuit before pushing the switch.
7. Push the switch to turn the light on and off.
8. Based on your observations, answer the questions below:
   a. After the wires are correctly connected (circuit), press the switch.

   What happened to the LED?
   b. Reverse the diode on the breadboard and press the switch. What

   happened to the LED?
9. Disconnect all wires and prepare for the next step in this activity.

Inventor's Logbook

Logbook 2.5

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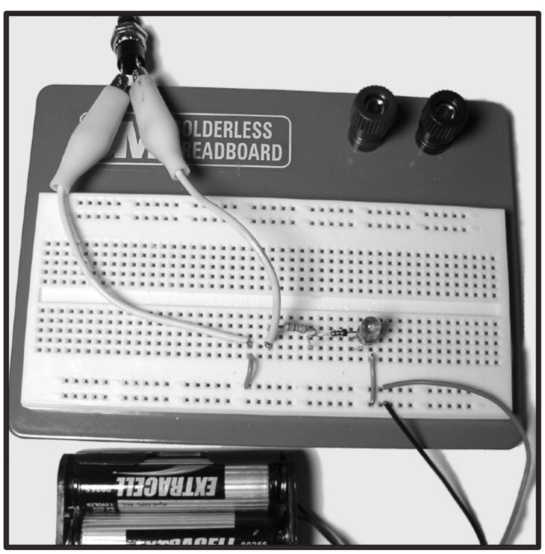
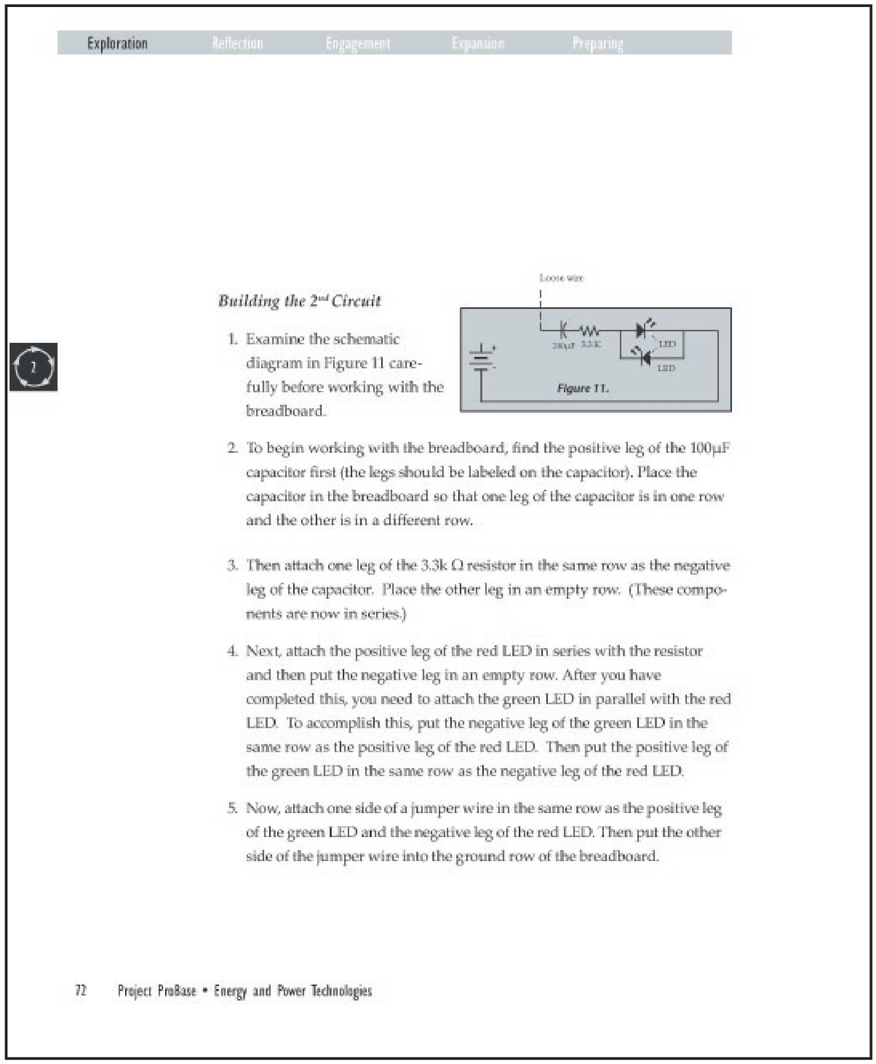
Students are asked to respond to the following questions:

1. After the wires are correctly connected (circuit), press the switch. What happened to the LED?
2. Reverse the diode on the breadboard and press the switch. What happened to the LED?





Exploration Reflection Engagement Expansion Preparing

Building the 2nd Circuit

1. Examine the schematic diagram in Figure 11 carefully before working with the breadboard.

Figure 11.

2. To begin working with the breadboard, find the positive leg of the 100µF capacitor first (the legs should be labeled on the capacitor). Place the capacitor in the breadboard so that one leg of the capacitor is in one row and the other is in a different row.

3. Then attach one leg of the 3.3k Ω resistor in the same row as the negative leg of the capacitor. Place the other leg in an empty row. (These components are now in series.)

4. Next, attach the positive leg of the red LED in series with the resistor and then put the negative leg in an empty row. After you have completed this, you need to attach the green LED in parallel with the red LED. To accomplish this, put the negative leg of the green LED in the same row as the positive leg of the red LED. Then put the positive leg of the green LED in the same row as the negative leg of the red LED.

5. Now, attach one side of a jumper wire in the same row as the positive leg of the green LED and the negative leg of the red LED. Then put the other side of the jumper wire into the ground row of the breadboard.

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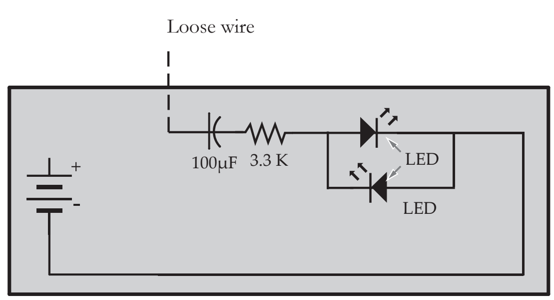
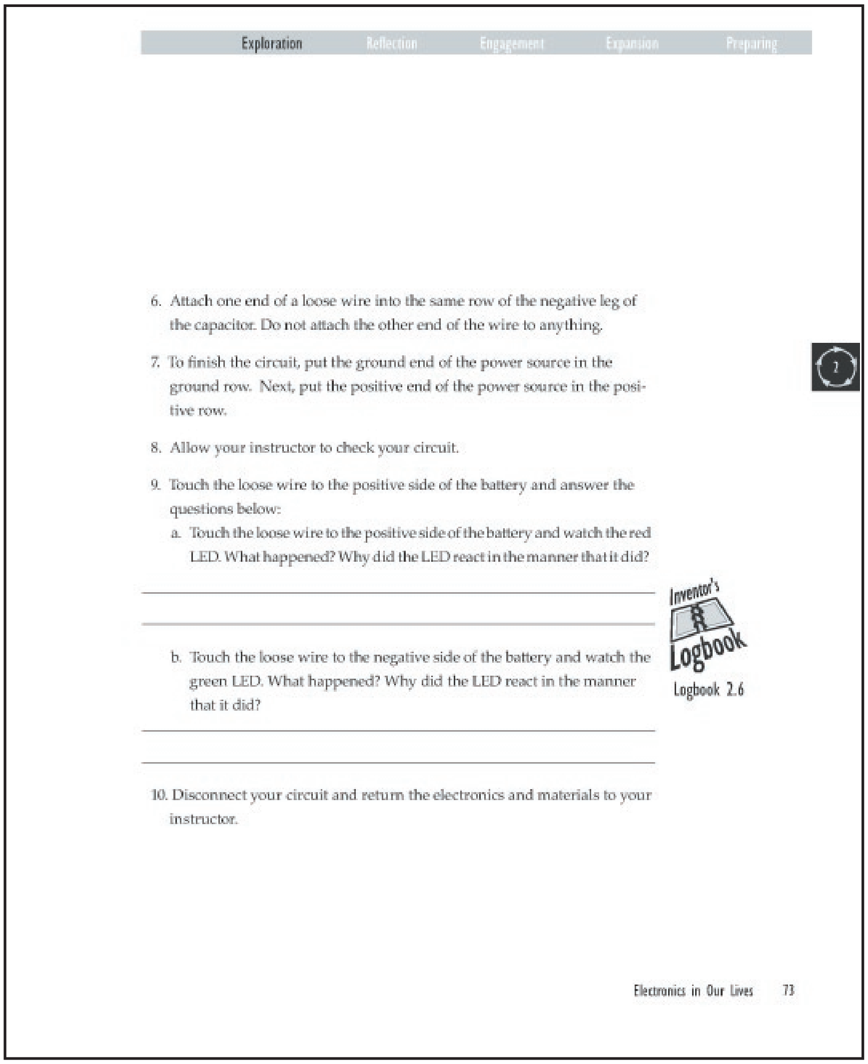


Figure 11.



6. Attach one end of a loose wire into the same row of the negative leg of the capacitor. Do not attach the other end of the wire to anything.
7. To finish the circuit, put the ground end of the power source in the ground row. Next, put the positive end of the power source in the positive row.
8. Allow your instructor to check your circuit.
9. Touch the loose wire to the positive side of the battery and answer the questions below:
   a. Touch the loose wire to the positive side of the battery and watch the red LED. What happened? Why did the LED react in the manner that it did?

   b. Touch the loose wire to the negative side of the battery and watch the green LED. What happened? Why did the LED react in the manner that it did?

Inventor's Logbook

Logbook 2.6

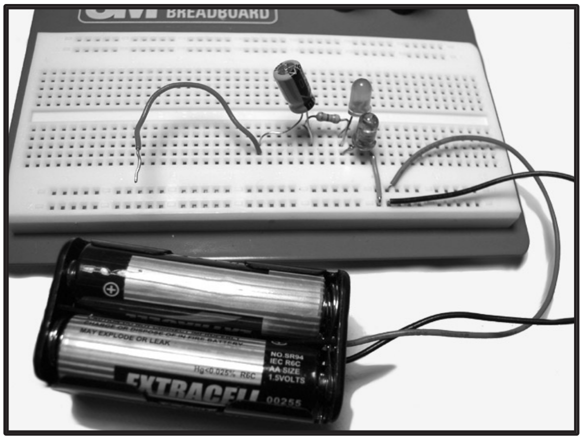
10. Disconnect your circuit and return the electronics and materials to your instructor.

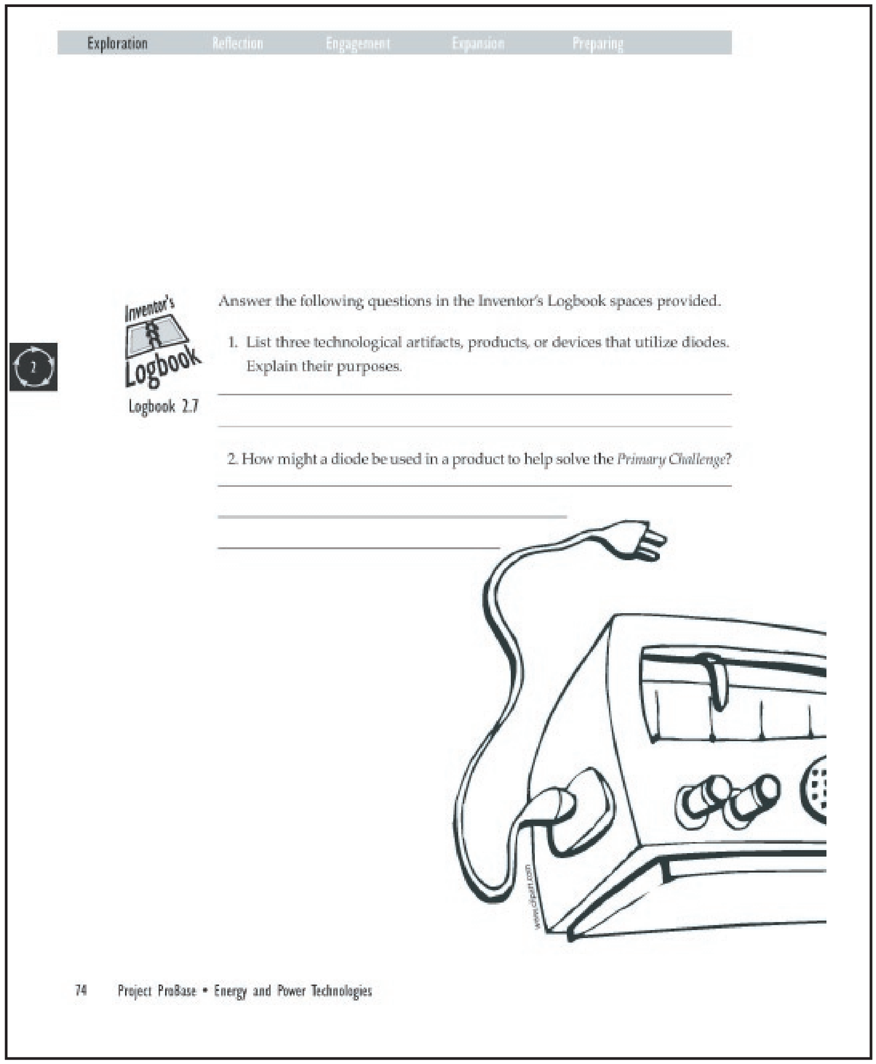
Students are asked to respond to the following questions:

1. Touch the loose wire to the positive side of the battery and watch the red LED. What happened? Why did the LED react in the manner that it did?

2. Touch the loose wire to the negative side of the battery and watch the green LED. What happened? Why did the LED react in the manner that it did?

2





Exploration Reflection Engagement Expansion Preparing

Inventor's Logbook

Logbook 2.7

Answer the following questions in the Inventor's Logbook spaces provided.

1. List three technological artifacts, products, or devices that utilize diodes. Explain their purposes.

2. How might a diode be used in a product to help solve the *Primary Challenge*?

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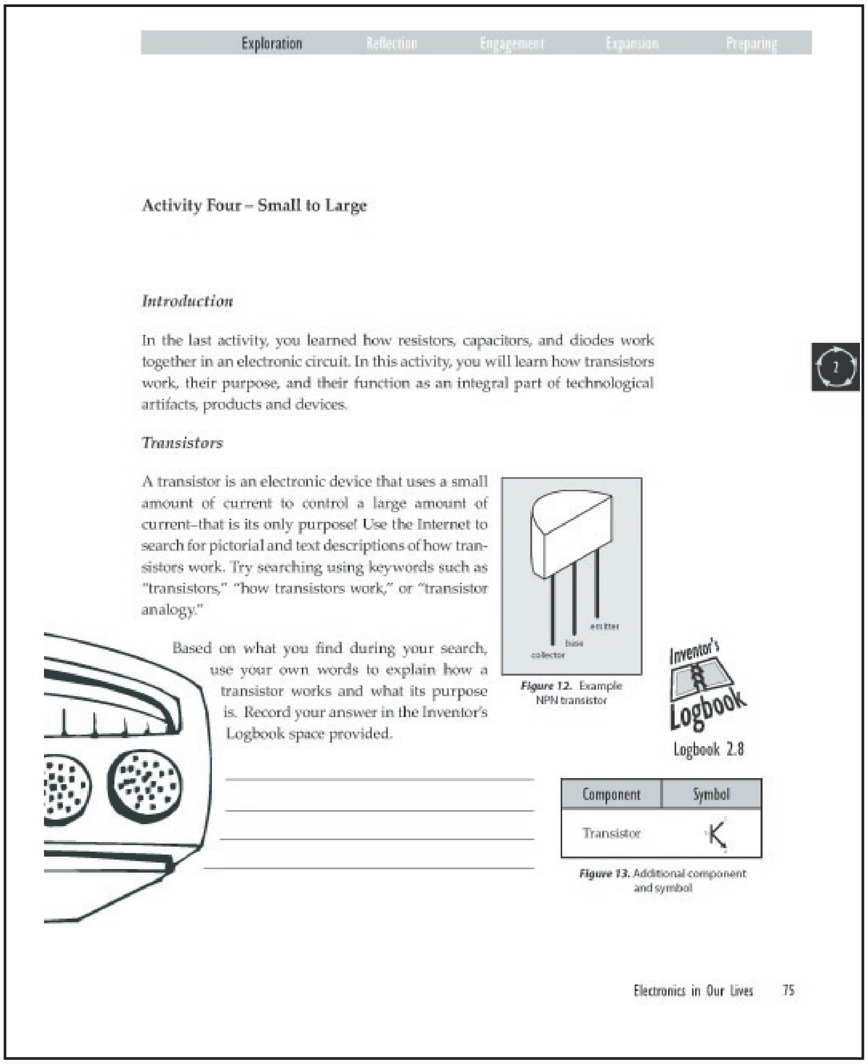
3. List three technological artifacts, products, or devices that utilize diodes. Explain their purposes.

4. How might a diode be used in a product to help solve the *Primary Challenge*?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Activity Four – Small to Large

Introduction

In the last activity, you learned how resistors, capacitors, and diodes work together in an electronic circuit. In this activity, you will learn how transistors work, their purpose, and their function as an integral part of technological artifacts, products and devices.

Transistors

A transistor is an electronic device that uses a small amount of current to control a large amount of current–that is its only purpose! Use the Internet to search for pictorial and text descriptions of how transistors work. Try searching using keywords such as "transistors," "how transistors work," or "transistor analogy."

Based on what you find during your search, use your own words to explain how a transistor works and what its purpose is. Record your answer in the Inventor's Logbook space provided.

emitter
base
collector

Figure 12. Example NPN transistor

Inventor's Logbook

Logbook 2.8

Component	Symbol
Transistor	

Figure 13. Additional component and symbol

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Activity Four – Small to Large

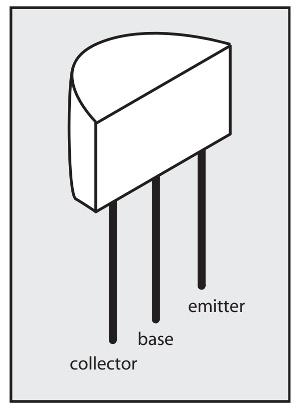
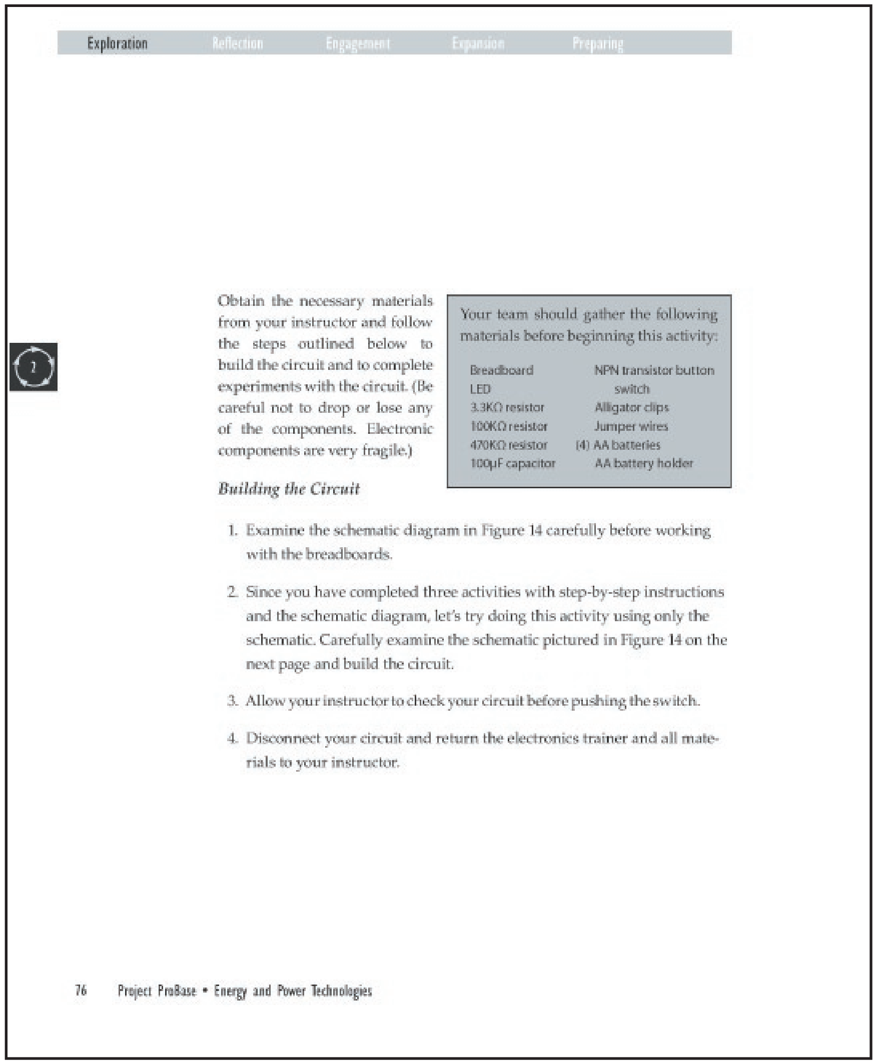


Figure 12. Example NPN transistor

Component	Symbol
Transistor	

Figure 13. Additional component and symbol



Exploration Reflection Engagement Expansion Preparing

Obtain the necessary materials from your instructor and follow the steps outlined below to build the circuit and to complete experiments with the circuit. (Be careful not to drop or lose any of the components. Electronic components are very fragile.)

Your team should gather the following materials before beginning this activity:

Breadboard	NPN transistor button switch
LED	Alligator clips
3.3KΩ resistor	Jumper wires
100KΩ resistor	(4) AA batteries
470KΩ resistor	AA battery holder
100µF capacitor	

Building the Circuit

1. Examine the schematic diagram in Figure 14 carefully before working with the breadboards.
2. Since you have completed three activities with step-by-step instructions and the schematic diagram, let's try doing this activity using only the schematic. Carefully examine the schematic pictured in Figure 14 on the next page and build the circuit.
3. Allow your instructor to check your circuit before pushing the switch.
4. Disconnect your circuit and return the electronics trainer and all materials to your instructor.

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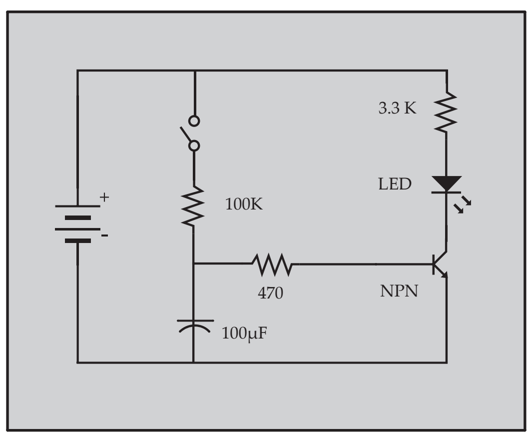


Figure 14.

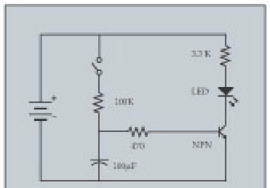


Figure 14.

Place answers to the questions listed below in the Inventor's Logbook spaces provided.

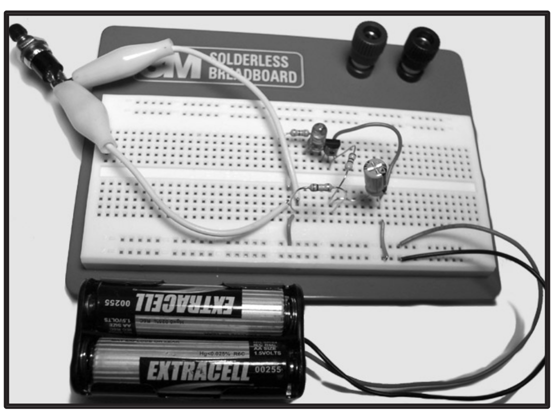
1. After completing the circuit, press and hold the switch. With the switch closed, all of the current flowing through the 100KW resistor is used to charge the capacitor. During this period, is the LED on or off? Why?

Inventor's Logbook

Logbook 2.9

2. When the capacitor voltage rises to 0.7V, the transistor will first turn on and the LED will light. As the capacitor voltage continues to rise, the current flowing through the 470KW resistor and into the transistor base will increase. Why does the current rise?

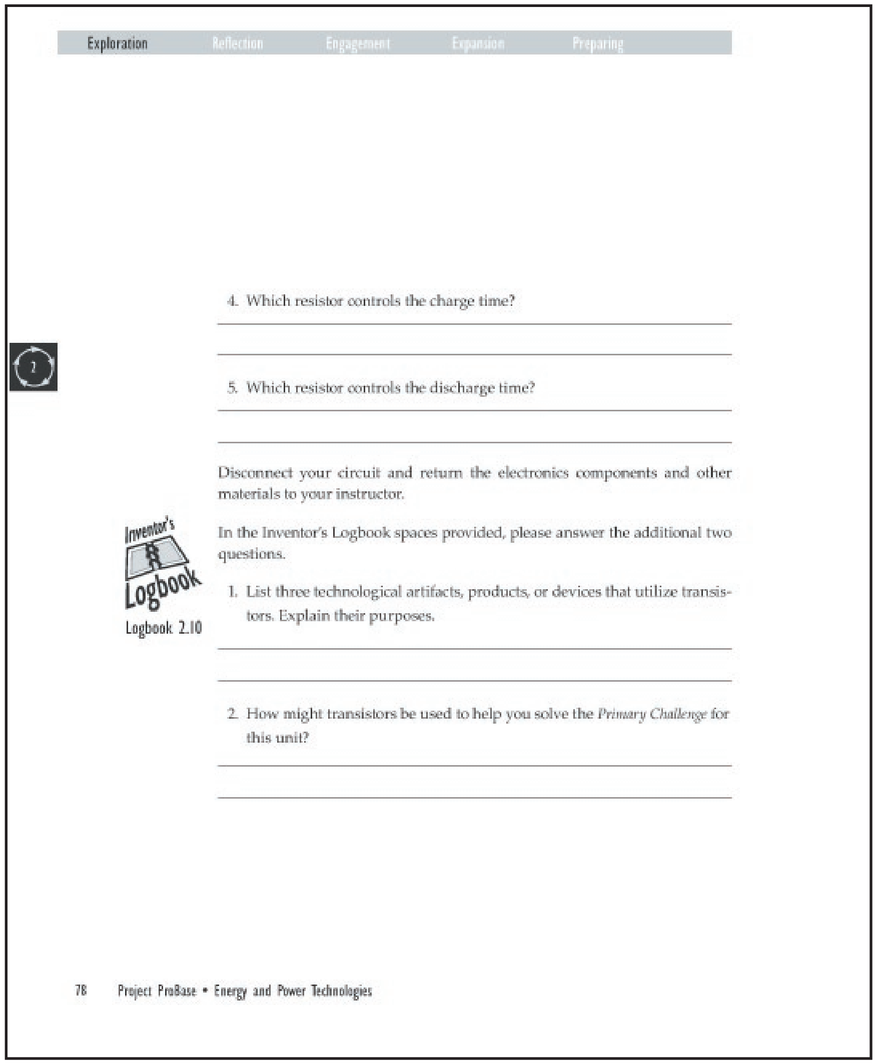
3. What happens to the capacitor when you release the switch? Can you explain why this occurred?



Students are asked to respond to the following questions:

1. After completing the circuit, press and hold the switch. With the switch closed, all of the current flowing through the 100KW resistor is used to charge the capacitor. During this period, is the LED on or off? Why?
2. When the capacitor voltage rises to 0.7V, the transistor will first turn on and the LED will light. As the capacitor voltage continues to rise, the current flow through the 470KW resistor and into the transistor base will increase. Why does the current rise?
3. What happens to the capacitor when you release the switch? Can you explain why this occurred?
4. Which resistor controls the charge time?
5. Which resistor controls the discharge time?

In the Inventor's Logbook space provided, please answer the additional two questions.


Exploration Reflection Engagement Expansion Preparing

4. Which resistor controls the charge time?

5. Which resistor controls the discharge time?

Disconnect your circuit and return the electronics components and other materials to your instructor.

Inventor's Logbook

Logbook 2.10

In the Inventor's Logbook spaces provided, please answer the additional two questions.

1. List three technological artifacts, products, or devices that utilize transistors. Explain their purposes.

2. How might transistors be used to help you solve the *Primary Challenge* for this unit?

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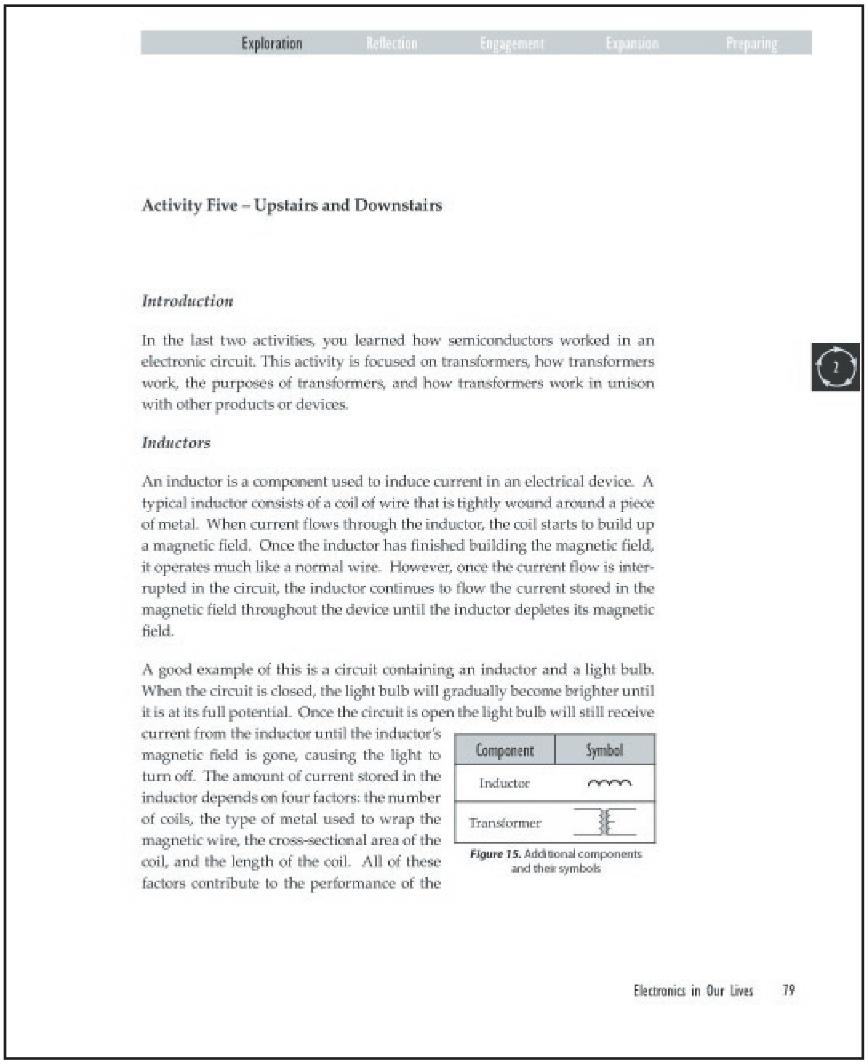
1. List three technological artifacts, products, or devices that utilize transistors. Explain their purposes.
2. How might transistors be used to help you solve the *Primary Challenge* for this unit?



Exploration | Reflection | Engagement | Expansion | Preparing

Activity Five – Upstairs and Downstairs

Introduction

In the last two activities, you learned how semiconductors worked in an electronic circuit. This activity is focused on transformers, how transformers work, the purposes of transformers, and how transformers work in unison with other products or devices.

Inductors

An inductor is a component used to induce current in an electrical device. A typical inductor consists of a coil of wire that is tightly wound around a piece of metal. When current flows through the inductor, the coil starts to build up a magnetic field. Once the inductor has finished building the magnetic field, it operates much like a normal wire. However, once the current flow is interrupted in the circuit, the inductor continues to flow the current stored in the magnetic field throughout the device until the inductor depletes its magnetic field.

A good example of this is a circuit containing an inductor and a light bulb. When the circuit is closed, the light bulb will gradually become brighter until it is at its full potential. Once the circuit is open the light bulb will still receive current from the inductor until the inductor's magnetic field is gone, causing the light to turn off. The amount of current stored in the inductor depends on four factors: the number of coils, the type of metal used to wrap the magnetic wire, the cross-sectional area of the coil, and the length of the coil. All of these factors contribute to the performance of the

Component	Symbol
Inductor	
Transformer	

Figure 15. Additional components and their symbols

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Component	Symbol
Inductor	
Transformer	

Figure 15. Additional components and their symbols

Activity Five – Upstairs and Downstairs

Students are asked to answer the following question:

Using a computer with access to the Internet, search for sites that explain how transformers work. Try searching using keywords such as "transformer," "primary coil," "secondary coil," "coils," "step-up," "step-down," or "input coils."

2

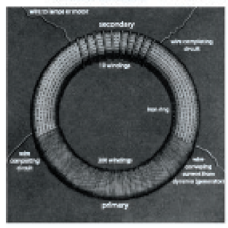
inductor.

Transformers

2

A basic transformer consists of two sets of coils or windings (coils of wire). Each set of windings is simply an inductor (a component that opposes changes in electrical current). AC voltage is applied to one of the windings, called the primary winding. The other winding (called the secondary winding) is positioned in close proximity to the primary winding, but is electrically isolated from it.

Figure 16.
Transformer basics



Transformers are used to convert electricity from one voltage to another with minimal loss of power. Transformers work only with AC because they require a changing magnetic field to be created in their core. Transformers can increase "voltage" (step-up) as well as reduce voltage (step-down). Alternating current flowing in the primary or input coil creates a continually changing magnetic field in the iron core of the coil. This field also passes through the secondary or output coil.

The changing strength of the magnetic field induces an alternating voltage in the secondary coil. In an electronics circuit, transformers are primarily used for converting voltages as well as isolating different circuits from each other.

Inventor's Logbook

Logbook 2.11

Using the Internet, search for sites that explain how transformers work. Try searching using keywords such as "transformer," "primary coil", "secondary coil," "coils," "step-up," "step-down," or "input coils."

Your team should gather the following materials before beginning this activity:

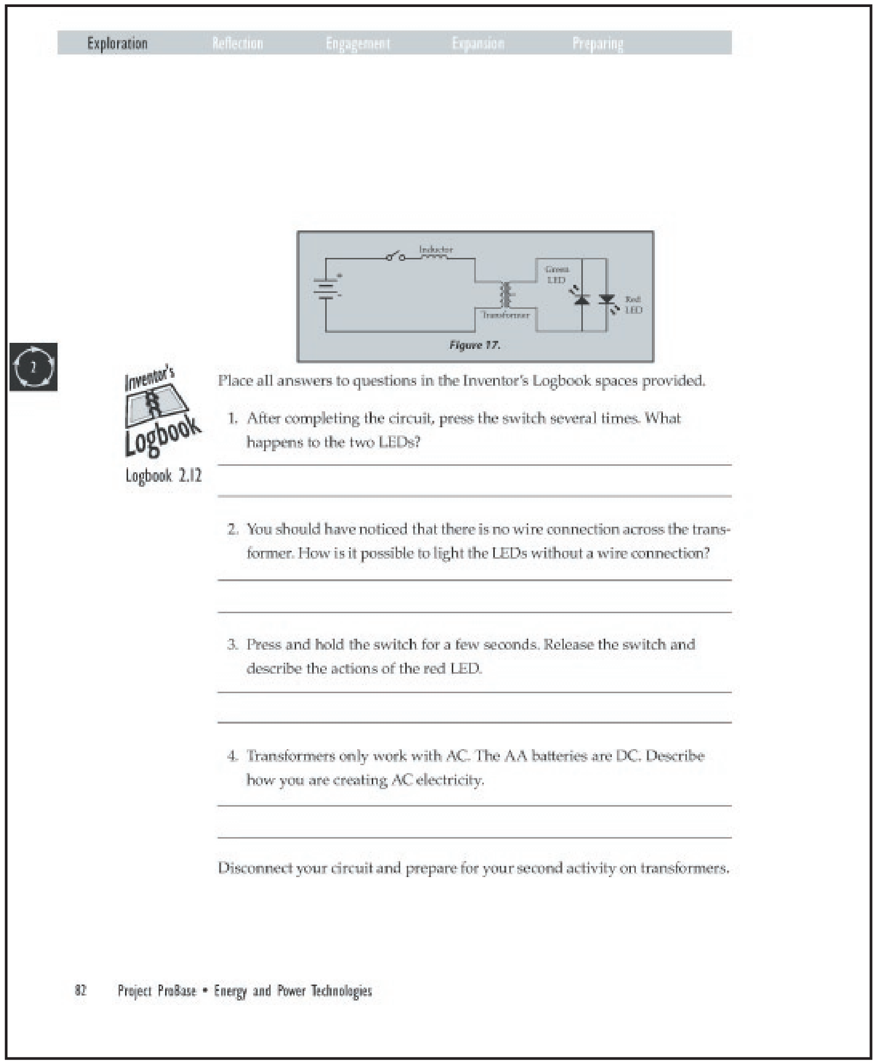
Breadboard	100µF capacitor
Red LED	NPN transistor
Green LED	Button switch
Transformer	Alligator clips
1MKΩ resistor	Jumper wires
100KΩ resistor	(4) AA batteries
10KΩ resistor	AA battery holder

In your own words, explain how a transformer works and what its purpose is. Record your answer in the Inventor's Logbook space provided.

Obtain the necessary materials from your instructor and follow the steps outlined below to build the circuit and complete experiments with the circuit. (Be careful not to drop or lose any of the components. Electronic components are very fragile.)

Building the 1st Circuit

1. Since you have completed four activities with step-by-step instructions and the schematic diagram, let's try doing this activity using only the schematic. Carefully examine the schematic pictured in Figure 17 on the next page and build the circuit.
2. You will first need to build an inductor to use in your circuit. To do this, tightly wind a large paper clip with 20' of magnetic wire. Make sure to leave about an 1 ½" of wire at both ends of the paper clip. You then need to sand the ends of the magnetic wire completely to remove the red coating. You have now made a simple inductor.
3. Once you have completed your circuit, allow your instructor to check your circuit before pushing the switch.



Exploration Reflection Engagement Expansion Preparing

Figure 17.

Inventor's Logbook

Logbook 2.12

Place all answers to questions in the Inventor's Logbook spaces provided.

1. After completing the circuit, press the switch several times. What happens to the two LEDs?

2. You should have noticed that there is no wire connection across the transformer. How is it possible to light the LEDs without a wire connection?

3. Press and hold the switch for a few seconds. Release the switch and describe the actions of the red LED.

4. Transformers only work with AC. The AA batteries are DC. Describe how you are creating AC electricity.

Disconnect your circuit and prepare for your second activity on transformers.

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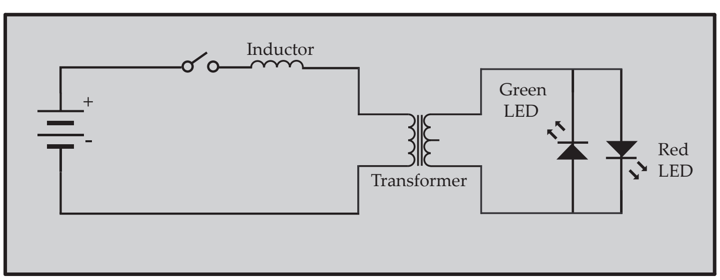
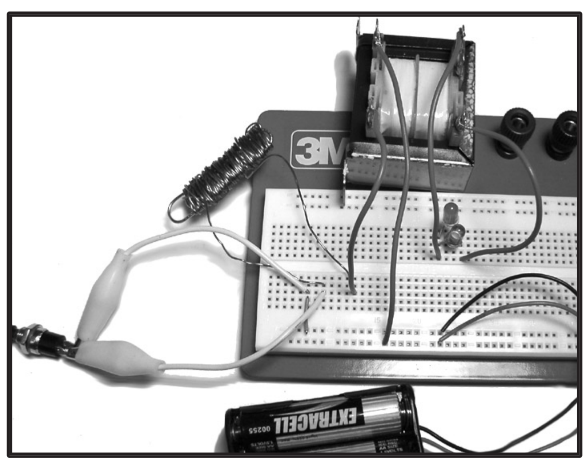
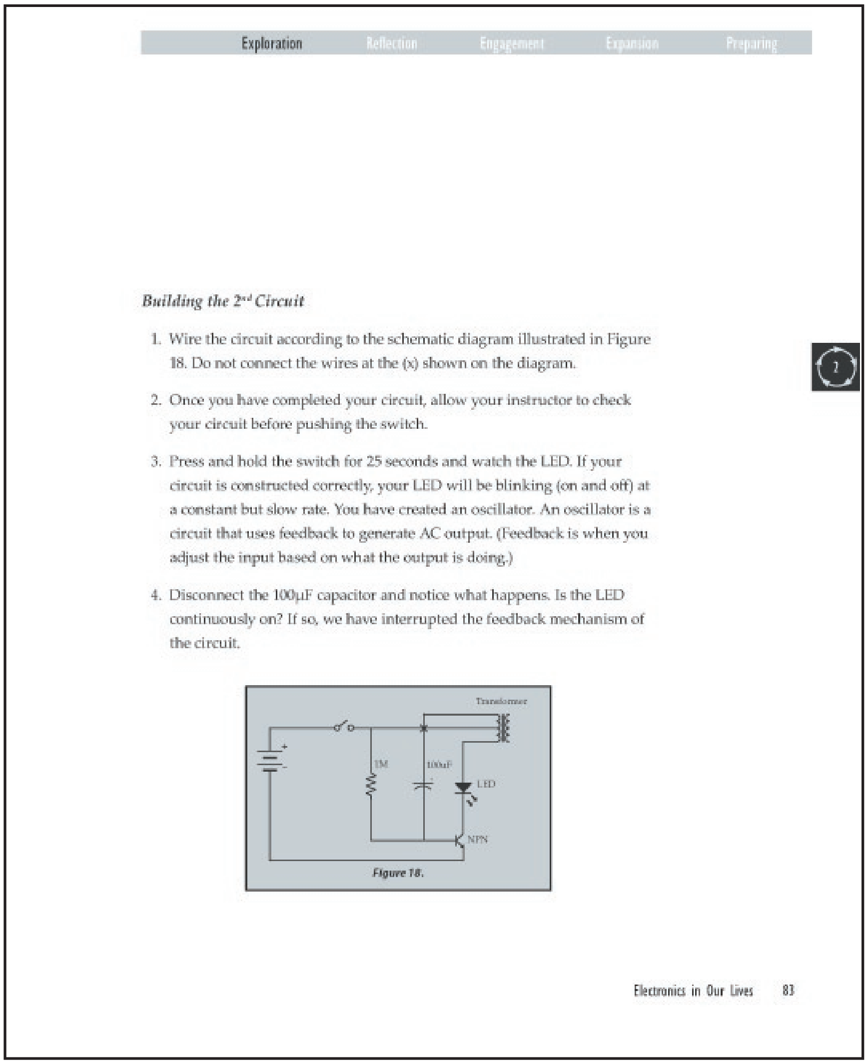


Figure 17.





Building the 2nd Circuit

1. Wire the circuit according to the schematic diagram illustrated in Figure 18. Do not connect the wires at the (x) shown on the diagram.
2. Once you have completed your circuit, allow your instructor to check your circuit before pushing the switch.
3. Press and hold the switch for 25 seconds and watch the LED. If your circuit is constructed correctly, your LED will be blinking (on and off) at a constant but slow rate. You have created an oscillator. An oscillator is a circuit that uses feedback to generate AC output. (Feedback is when you adjust the input based on what the output is doing.)
4. Disconnect the 100µF capacitor and notice what happens. Is the LED continuously on? If so, we have interrupted the feedback mechanism of the circuit.

Transformer 1M 100uF LED NPN

Figure 18.

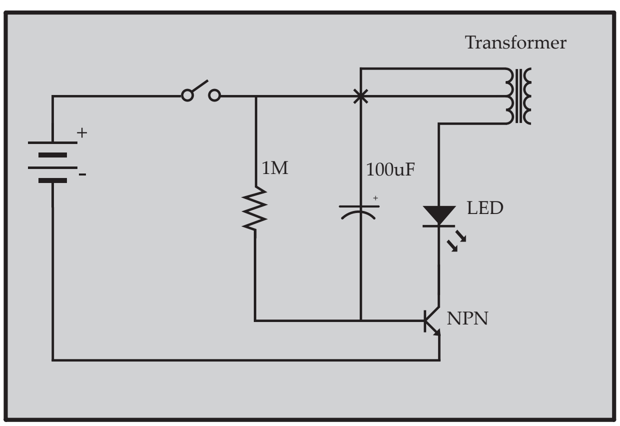
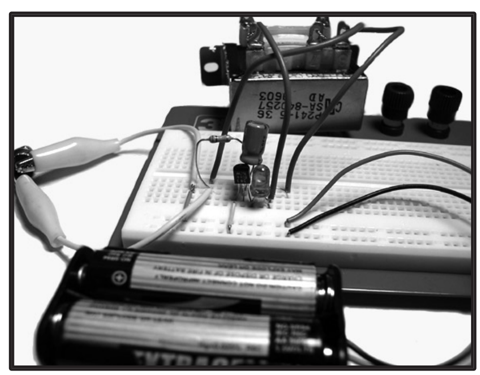


Figure 18.



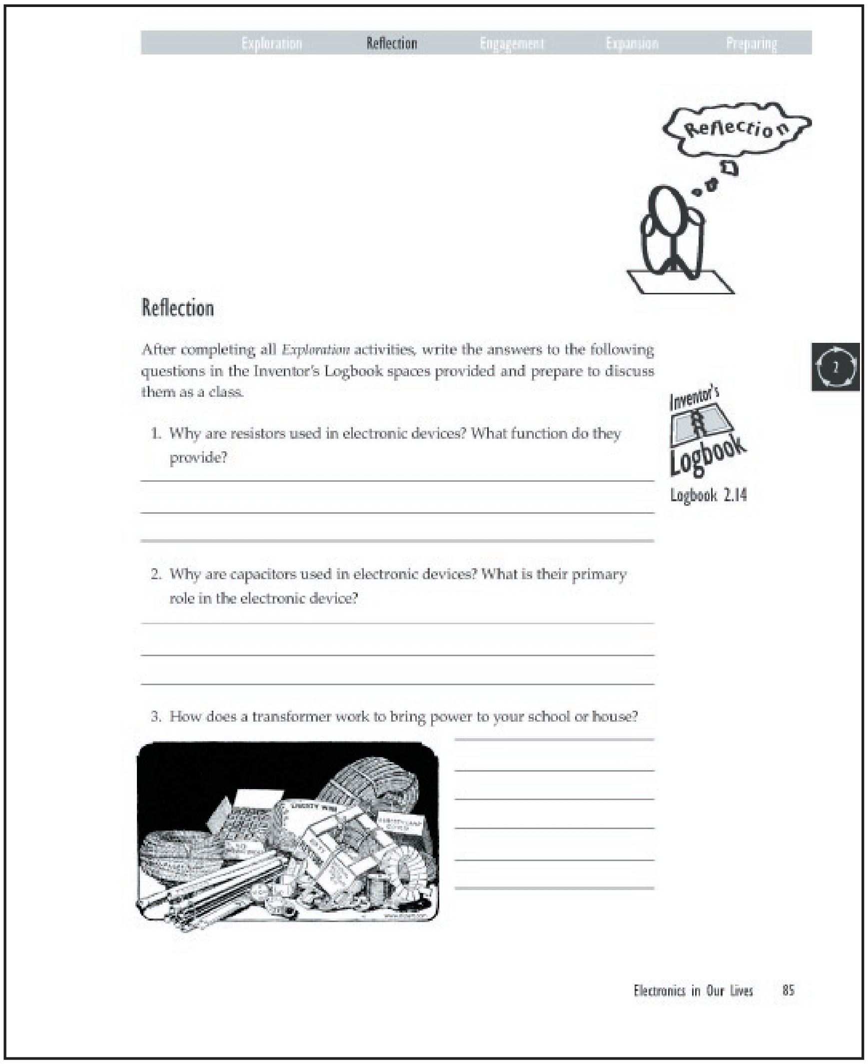
Inventor's Logbook

Logbook 2.13

5. Reconnect the capacitor to the original circuit as in Figure 18.
6. Replace the 1M resistor with the 100K resistor. What did you discover?

7. Replace the 100K resistor with the 10K resistor. What did you discover?

Disconnect the circuit and return the electronics and materials to your instructor.



Exploration Reflection Engagement Expansion Preparing

Reflection

After completing all *Exploration* activities, write the answers to the following questions in the Inventor's Logbook spaces provided and prepare to discuss them as a class.

Inventor's Logbook

Logbook 2.14

1. Why are resistors used in electronic devices? What function do they provide?

2. Why are capacitors used in electronic devices? What is their primary role in the electronic device?

3. How does a transformer work to bring power to your school or house?

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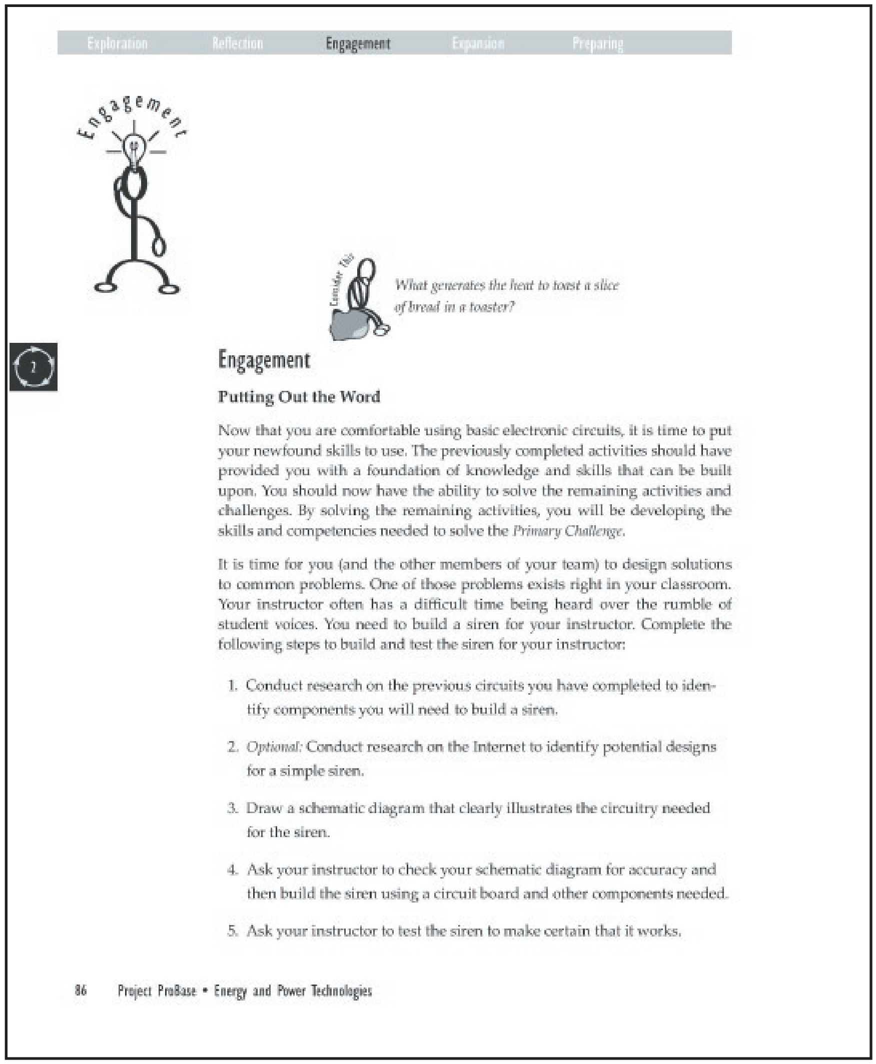
Reflection

After students complete all of the *Exploration* activities, lead a discussion centertin on the following questions:

1. Why are resistors used in electronic devices? What function do they provide?
2. Why are capacitors used in electronic devices? What is their primary role in electronic devices?
3. How does a transformer work to bring power to your school or house?

Engagement

At this phase of the learning cycle, students should be comfortable using simple electronic devices and feel ready to move on to more challenging activities. All of the activities that the students completed provided a foundation of knowledge and skills. This foundation will gives students the abilities to solve the remaining activities and provides the knowledge and skills to help solve the *Primary Challenge*.



What generates the heat to toast a slice of bread in a toaster?

Engagement

Putting Out the Word

Now that you are comfortable using basic electronic circuits, it is time to put your newfound skills to use. The previously completed activities should have provided you with a foundation of knowledge and skills that can be built upon. You should now have the ability to solve the remaining activities and challenges. By solving the remaining activities, you will be developing the skills and competencies needed to solve the *Primary Challenge*.

It is time for you (and the other members of your team) to design solutions to common problems. One of those problems exists right in your classroom. Your instructor often has a difficult time being heard over the rumble of student voices. You need to build a siren for your instructor. Complete the following steps to build and test the siren for your instructor:

1. Conduct research on the previous circuits you have completed to identify components you will need to build a siren.
2. *Optional:* Conduct research on the Internet to identify potential designs for a simple siren.
3. Draw a schematic diagram that clearly illustrates the circuitry needed for the siren.
4. Ask your instructor to check your schematic diagram for accuracy and then build the siren using a circuit board and other components needed.
5. Ask your instructor to test the siren to make certain that it works.

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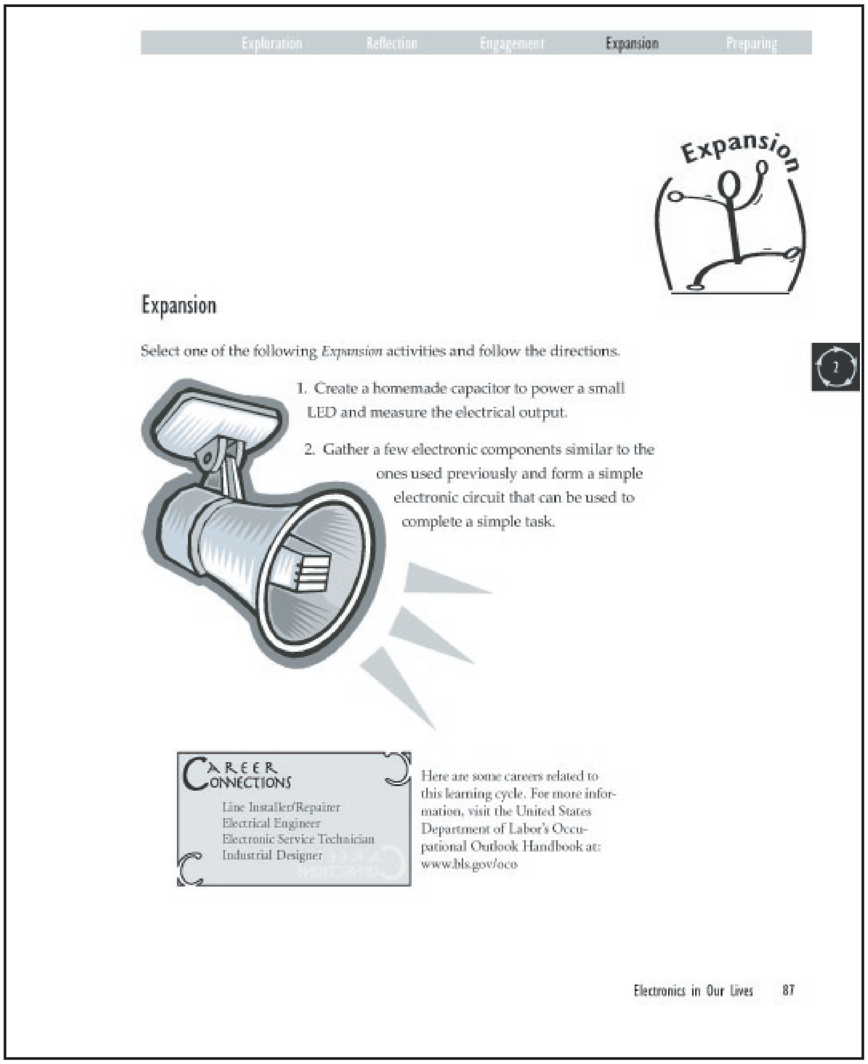
Putting out the Word

In this *Engagement*, students will work in teams to solve an electronics design problem that might be found in most secondary school classrooms. Essentially, students will work from a schematic drawing to construct a siren that could be used to call the class to order. Ask the students to follow the design loop and the steps outlined below as they complete this design challenge.

1. Conduct research on the previous circuits you have completed to identify components you will need to build a siren.
2. *Optional*: Conduct Internet research to identify potential designs for a simple siren.
3. Draw a schematic diagram that clearly illustrates the circuitry needed for the siren.
4. Ask your instructor to check your schematic diagram for accuracy and then build the siren using a circuit board and other components needed.
5. Ask your instructor to test the siren to make certain that it works.



Exploration Reflection Engagement Expansion Preparing

Expansion

Select one of the following *Expansion* activities and follow the directions.

1. Create a homemade capacitor to power a small LED and measure the electrical output.
2. Gather a few electronic components similar to the ones used previously and form a simple electronic circuit that can be used to complete a simple task.

CAREER CONNECTIONS

Line Installer/Repairer
Electrical Engineer
Electronic Service Technician
Industrial Designer

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

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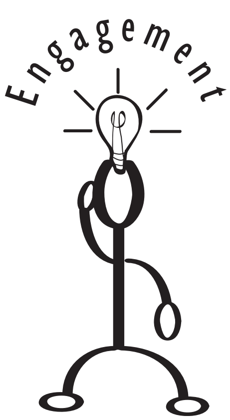
Expansion

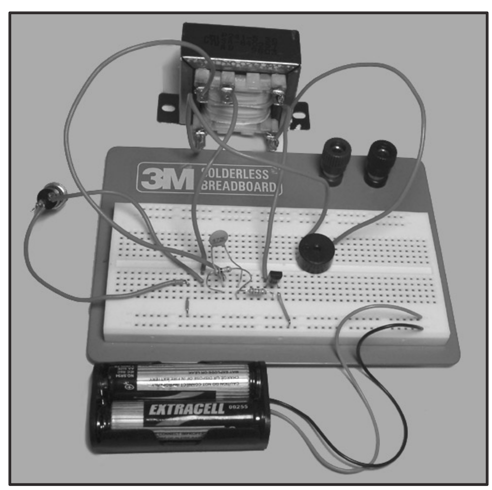
Although not required, these *Expansion* activities are designed to cause teams to delve deeper into the concepts explored in this learning cycle.

Students should select only one of the following *Expansion* options.

1. Create a homemade capacitor to power a small LED and measure the electrical output.
2. Gather a few electronic components similar to the ones used previously and form a simple electronic circuit that can be used to complete a simple task.

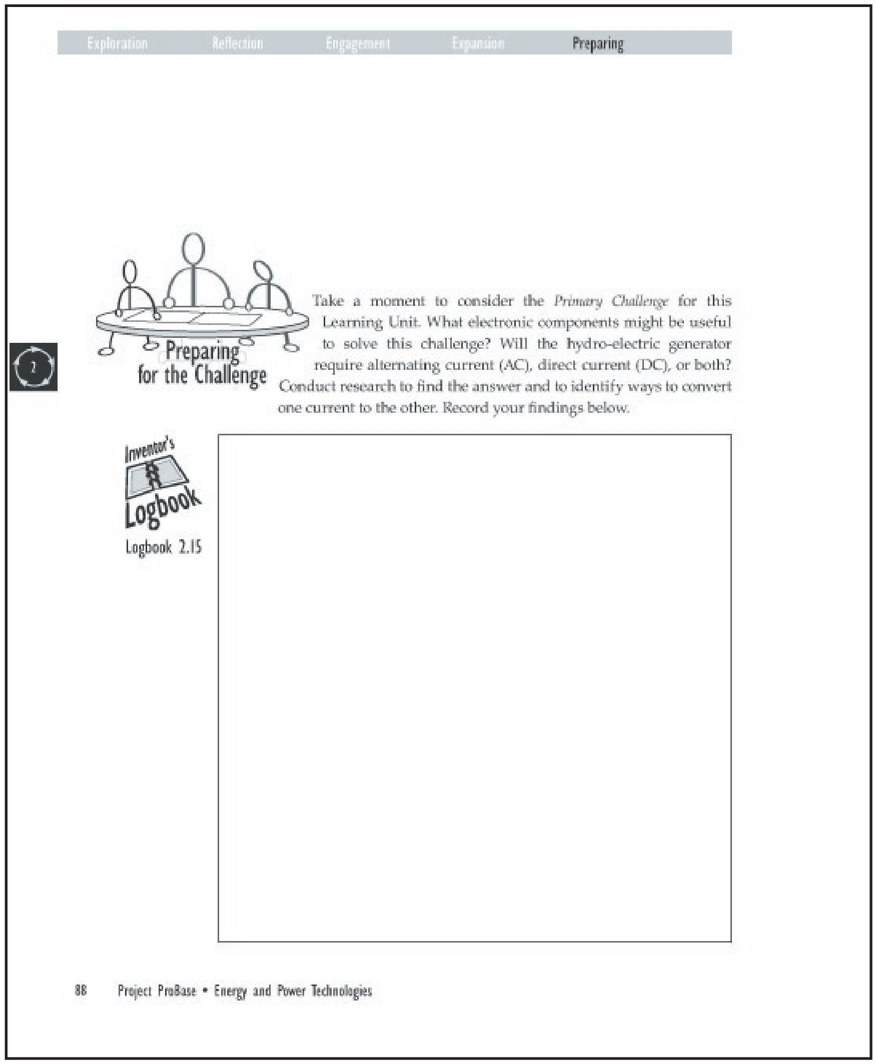


Possible *Engagement* solution schematic



Preparing for the Challenge

Now that the students have completed all the activities associated with this learning cycle, they need to consider the bigger picture of energy and power and how electronics relates to the *Primary Challenge.*


Exploration Reflection Engagement Expansion Preparing

Preparing for the Challenge

Take a moment to consider the *Primary Challenge* for this Learning Unit. What electronic components might be useful to solve this challenge? Will the hydro-electric generator require alternating current (AC), direct current (DC), or both? Conduct research to find the answer and to identify ways to convert one current to the other. Record your findings below.

Inventor's Logbook

Logbook 2.15

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Teaching Tips

In *Preparing for the Challenge*, provide class time for your students to research to find answers to the following questions. At the end of their research time, discuss their findings.

1. What electronic components might be useful to solve this challenge?
2. Will your *Primary Challenge* solution require alternating current (AC), direct current (DC), or both? Can you convert one to the other?

Student Assessment

An assessment rubric has been developed for the *Exploration* and *Engagement* activities. Feel free to change this rubric to better suit your particular needs.

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Element	Criteria				Points
	4	3	2	1	
Exploration Circuit Completion	Each circuit and/or activity was successfully completed.	Each circuit/activity was successfully completed.	Most circuits/ activities were successfully completed.	Less than half of the circuits/ activities were successfully completed.	
Questions	All questions for each activity were answered, with high quality and effort.	All questions for each activity were answered with effort.	Most questions for each activity were answered, more effort and detail needed.	Questions incomplete, no effort shown.	
Inventor's Logbook Questions	All questions were correctly answered and placed in the Inventor's Logbook entry spaces.	Nearly all questions were correctly answered and placed in the Inventor's Logbook entry spaces.	Most questions were correctly answered and placed in the Inventor's Logbook entry spaces.	The majority of the questions were answered incorrectly or did not provide the needed information.	
Engagement Schematic	Schematic shows high detail and accuracy; illustrates circuitry needed for working solution; applies concepts and components developed during *Exploration*; adds extra components.	Schematic shows detail and accuracy; illustrates circuitry needed for working solution; applies most concepts and components developed during *Exploration*.	Portions of schematic are strong; some areas still need development and refinement; need to apply more concepts from *Exploration*.	Schematic is incomplete and needs improvement; does not apply concepts from *Exploration*.	
Siren construction	Siren is fully functional; effectively gets class's attention.	Siren is fully functional.	Siren functions, but not as desired.	Siren does not function.	
Safety Procedures	All safety procedures were followed.	Most safety procedures were followed.	Some safety procedures were followed.	Safety procedures were disregarded.	
				Total Points	

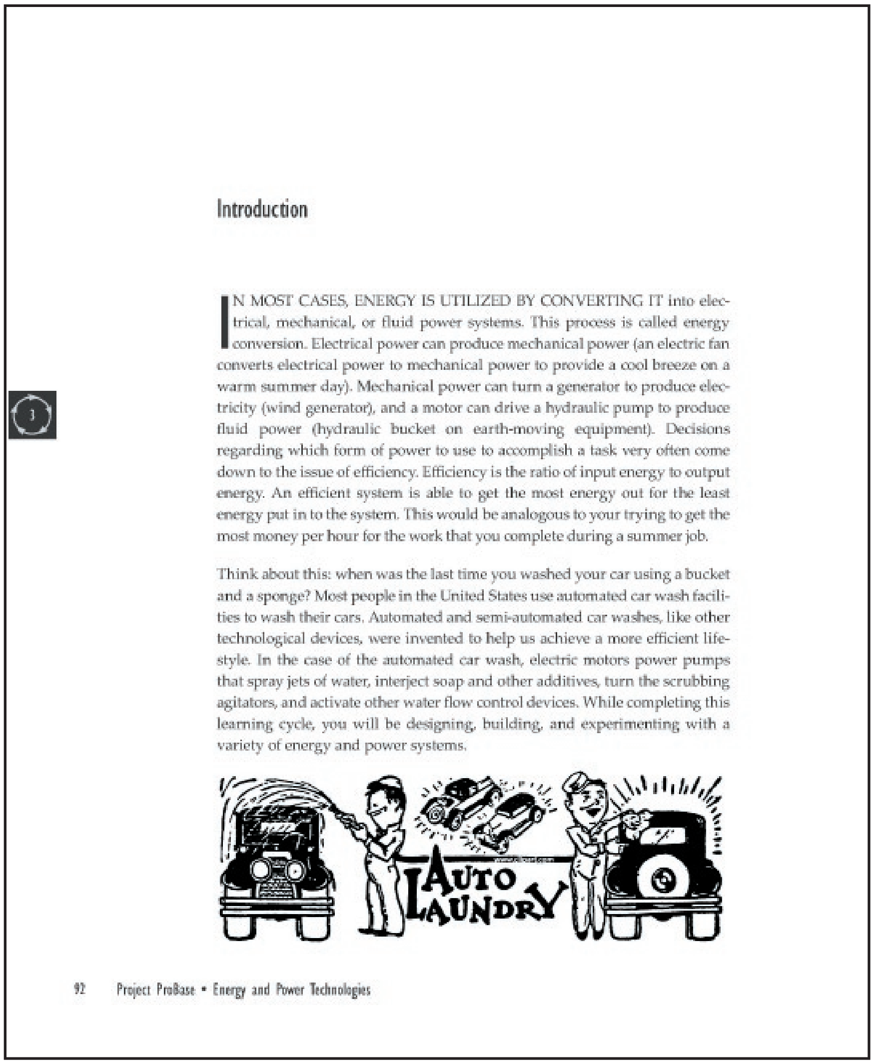
Learning Cycle Three

Mechanical Devices in Our Lives

Mechanical Devices in Our Lives

Introduction

This learning cycle focuses on fluid and mechanical power. Students will be engaged in hands-on activities that will enable them to put the theory of mechanical principles to the test and include these concepts in their solutions to the *Primary Challenge.* Students will explore simple machines and fluid power systems in the *Exploration* phase of this learning cycle. In the *Engagement* phase, they are challenged to put this knowledge to work as they design a system that moves water.



Introduction

IN MOST CASES, ENERGY IS UTILIZED BY CONVERTING IT into electrical, mechanical, or fluid power systems. This process is called energy conversion. Electrical power can produce mechanical power (an electric fan converts electrical power to mechanical power to provide a cool breeze on a warm summer day). Mechanical power can turn a generator to produce electricity (wind generator), and a motor can drive a hydraulic pump to produce fluid power (hydraulic bucket on earth-moving equipment). Decisions regarding which form of power to use to accomplish a task very often come down to the issue of efficiency. Efficiency is the ratio of input energy to output energy. An efficient system is able to get the most energy out for the least energy put in to the system. This would be analogous to your trying to get the most money per hour for the work that you complete during a summer job.

Think about this: when was the last time you washed your car using a bucket and a sponge? Most people in the United States use automated car wash facilities to wash their cars. Automated and semi-automated car washes, like other technological devices, were invented to help us achieve a more efficient lifestyle. In the case of the automated car wash, electric motors power pumps that spray jets of water, interject soap and other additives, turn the scrubbing agitators, and activate other water flow control devices. While completing this learning cycle, you will be designing, building, and experimenting with a variety of energy and power systems.

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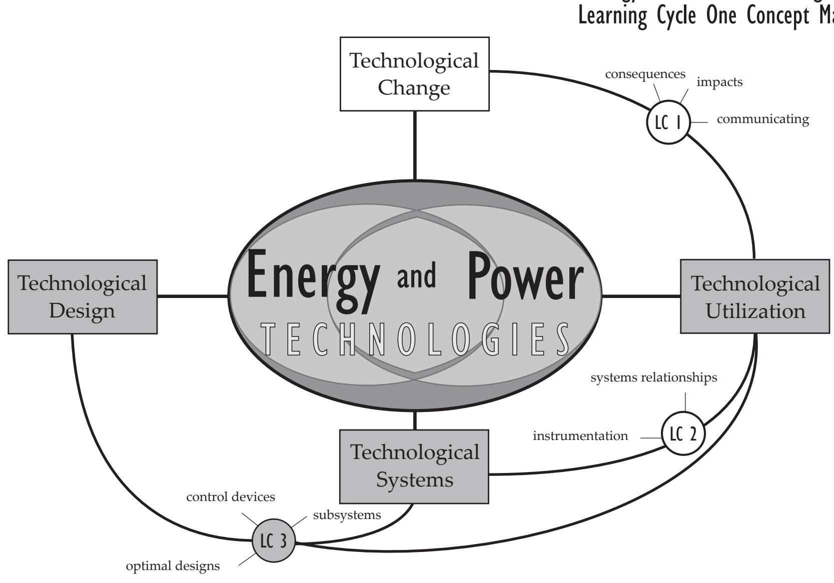
Objectives and Essential Questions

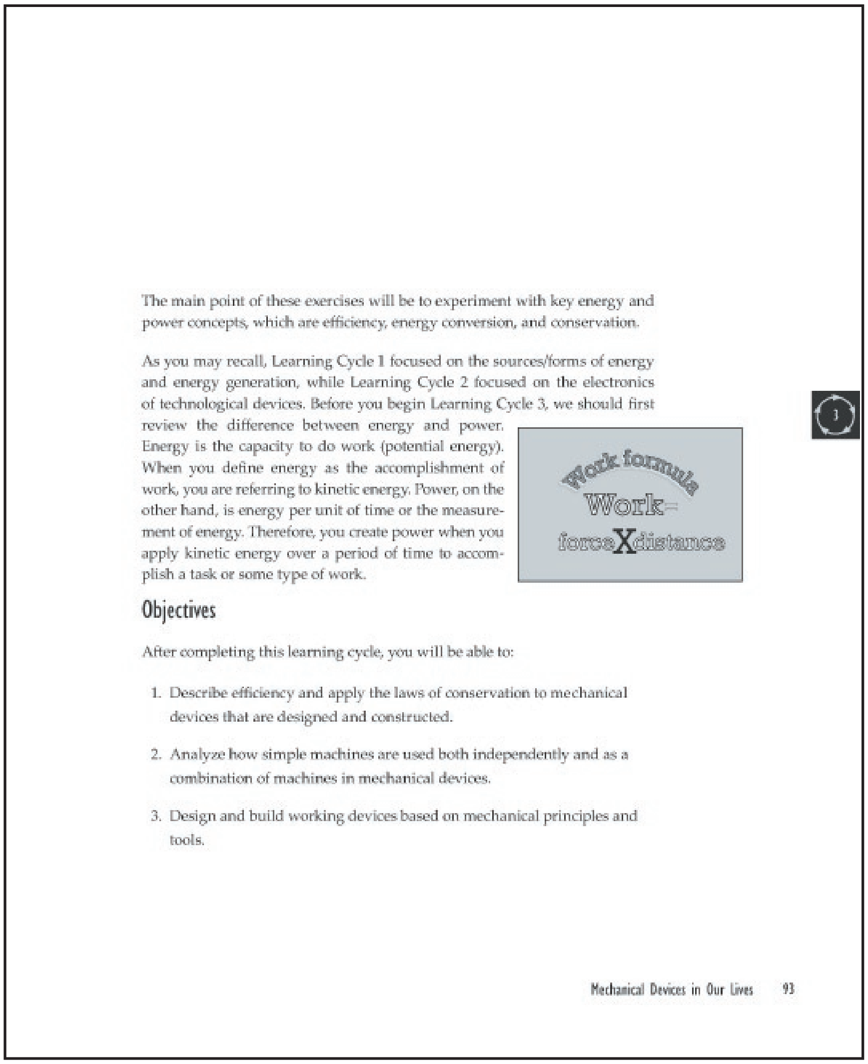
After completing this learning cycle, students will be able to:

1. Describe efficiency and apply energy conversion to mechanical devices that are designed and constructed.

Essential Question 5c: To what extent have optimal designs been achieved in the eight technological context areas?

Energy and Power Technologies
Learning Cycle One Concept Map




The main point of these exercises will be to experiment with key energy and power concepts, which are efficiency, energy conversion, and conservation.

As you may recall, Learning Cycle 1 focused on the sources/forms of energy and energy generation, while Learning Cycle 2 focused on the electronics of technological devices. Before you begin Learning Cycle 3, we should first review the difference between energy and power. Energy is the capacity to do work (potential energy). When you define energy as the accomplishment of work, you are referring to kinetic energy. Power, on the other hand, is energy per unit of time or the measurement of energy. Therefore, you create power when you apply kinetic energy over a period of time to accomplish a task or some type of work.

Objectives

After completing this learning cycle, you will be able to:

1. Describe efficiency and apply the laws of conservation to mechanical devices that are designed and constructed.
2. Analyze how simple machines are used both independently and as a combination of machines in mechanical devices.
3. Design and build working devices based on mechanical principles and tools.

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2. Analyze how simple machines are used both independently and as a combination of machines in mechanical devices.

Essential Question 4a: What are the systems and subsystems involved in the various contexts of technology?

3. Design and build working devices based on mechanical principles and tools.

Essential Question 9a: How are technologies used to control devices and systems?

Facility Requirements

No special facility requirements are needed as long as students have access to computers with Internet access and a place to design and build their devices.

Equipment and Materials

Based on a class of 28 students

Miscellaneous wood
Wood craft sticks
Paper and cardboard stock
Miscellaneous plastics
String/twine
Screws and nails
Bolts and nuts
Glue gun and glue
Duct tape
Tape measures
Files
Hack saws
Sandpaper

Exploration: Challenge One (Materials may alter according to designs)
Newton scale
Pulleys

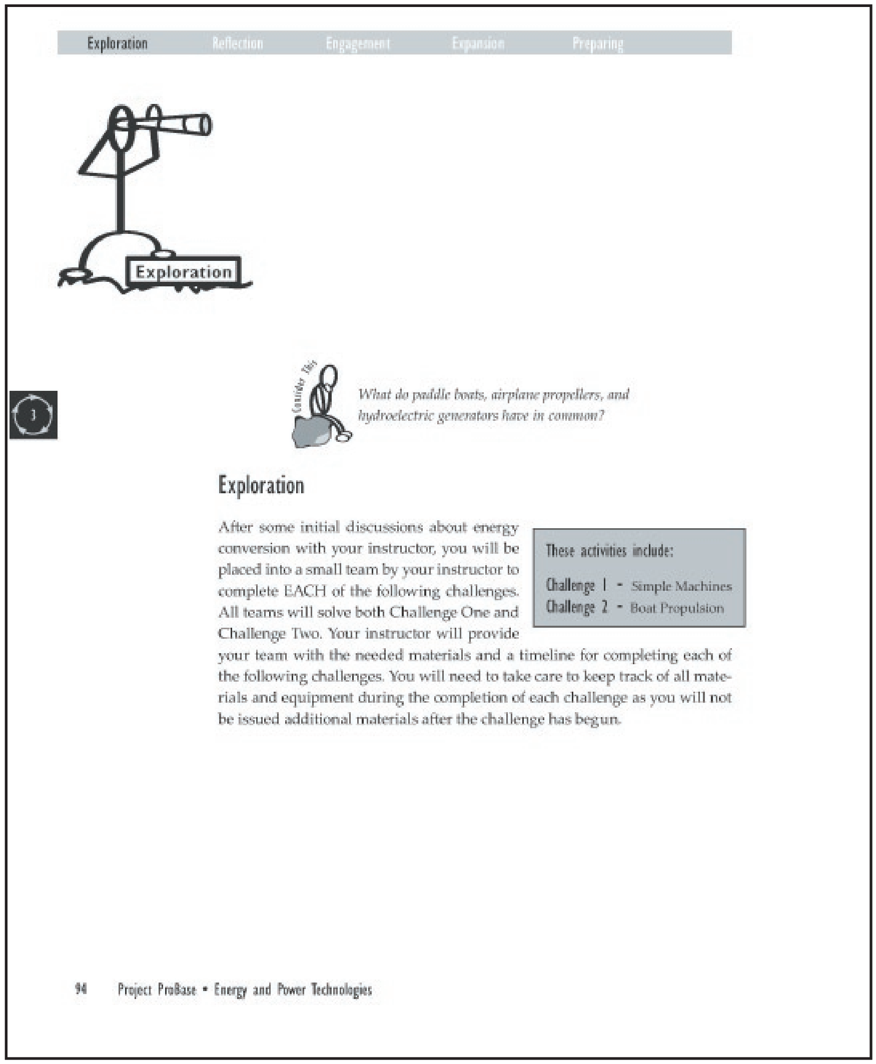
Exploration: Challenge Two (Materials may alter according to designs)
(7) 4" x 8" Blocks of wood or foam
(7) Small DC motors
(7) AA batteries and battery holders
(7) DC motor mounts
Stop watch
Plastic chains

Engagement
Miscellaneous PVC pipe and fittings
One gallon of water
Plastic hose

Suggested Daily Outline

Day One	Day Two
Introduction *Exploration* Challenge 1	*Exploration*
Day Three	**Day Four**
Exploration	*Exploration* Challenge 2
Day Five	**Day Six**
Exploration	*Exploration, Reflection*
Day Seven	**Day Eight**
Engagement	*Engagement*
Day Nine	**Day Ten**
Engagement	*Engagement*
Day Eleven	
Preparing for the Challenge	

Estimated number of 50-minute class periods: **11**


Exploration Reflection Engagement Expansion Preparing

Exploration

What do paddle boats, airplane propellers, and hydroelectric generators have in common?

Exploration

After some initial discussions about energy conversion with your instructor, you will be placed into a small team by your instructor to complete EACH of the following challenges. All teams will solve both Challenge One and Challenge Two. Your instructor will provide your team with the needed materials and a timeline for completing each of the following challenges. You will need to take care to keep track of all materials and equipment during the completion of each challenge as you will not be issued additional materials after the challenge has begun.

These activities include:

Challenge 1 - Simple Machines
Challenge 2 - Boat Propulsion

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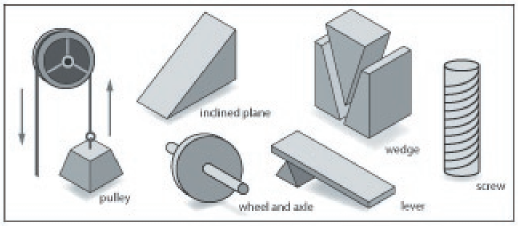
Exploration

For six days, students will be engaged in two different energy and power activities.

Students are required to complete the following task for Challenge One:

Using one or more of the six simple machines outlined, students are asked to build a device that will safely lift one of their teammates from the floor to a height of six inches. Teams are asked to demonstrate their solutions to the rest of the class. Make sure the students utilize the design problem-solving process (the design loop) to solve this engineering design problem.



Challenge One: Simple Machines

Almost every task performed by humans is accomplished by using various combinations of the six simple machines. The six simple machines include: the lever, pulley, wheel and axle, inclined plane, wedge, and screw. The technology teacher at your local middle school introduces simple machines to seventh grade students through a lengthy lecture using the white board. You might even remember the lecture – a real sleeper! At a recent Technology Department meeting, the Department Chair suggested that all new concepts should be introduced to students using a problem-based, hands-on approach. This challenged the technology teachers to look for creative ways to change their teaching practices.

The middle school teacher is good friends with your instructor and volunteered to help her find a way to make simple machines more exciting. Your instructor developed this idea and believes it needs to be tested with real students. Your team will assist your instructor by prototyping this idea before it is shared with other technology teachers and the world!

Teaching Tips

The concept of mechanical advantage can be discussed prior to the completion of Challenge One. Simple machines make jobs easier by using a small force in order to overcome a large force, giving a mechanical advantage. Mechanical advantage can be calculated by dividing the load (output force) by the effort (input force).

Mechanical advantage = output force/input force

Teaching Tips

Details for each challenge are provided in the Student's Guide. Please refer to the guide for the materials needed for each challenge. The water tank will need to be constructed prior to Challenge Two of this *Exploration*. You should begin to construct this as your students are working on their first challenge activity.

Teaching tips

You may decide to have students propose a materials list based on their design, or have the students design their devices according to the materials you provide.

Possible materials include:

- Miscellaneous wood
- Screws/nails
- Newton scale
- Tape measure
- String/ twine
- Paper and cardboard
- Pulleys
- Bolts/ nuts
- Glue guns and glue

3

Exploration Reflection Engagement Expansion Preparing

Task

Using one or a combination of the six simple machines, build a device that will (using the least possible force) safely lift one of your teammates from the floor to a height of six inches. Be prepared to demonstrate your solution to this problem to the other teams/members of your class. Make sure that you utilize the design problem-solving process (the design loop) to solve this engineering design problem.

Design Criteria

To adequately solve this design problem, your team will need to strictly adhere to the following design criteria:

- Design teams must use only materials and tools supplied at the beginning of the design challenge.
- Completed prototype must (at a minimum) use all six simple machines.
- Completed prototype must be submitted with a credible sketch of the device.
- Completed prototype must not place your classmate in harm's way at any time and must operate safely during product testing.
- Completed prototype must be capable of lifting your classmate to a height of six inches (from the floor) and hold her/him there for at least two minutes.
- Completed prototype must include labels for each of the six simple machines (note: simple machines may be used more than once).

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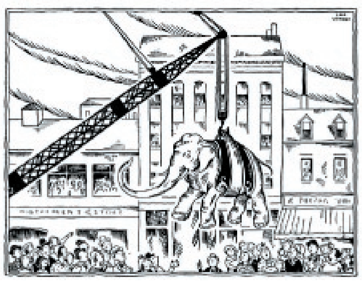
- Completed prototypes must utilize the least possible input force to accomplish the task.
- The completed prototype must include a connection point where a spring scale can be attached in order to measure input force.



Testing the Device

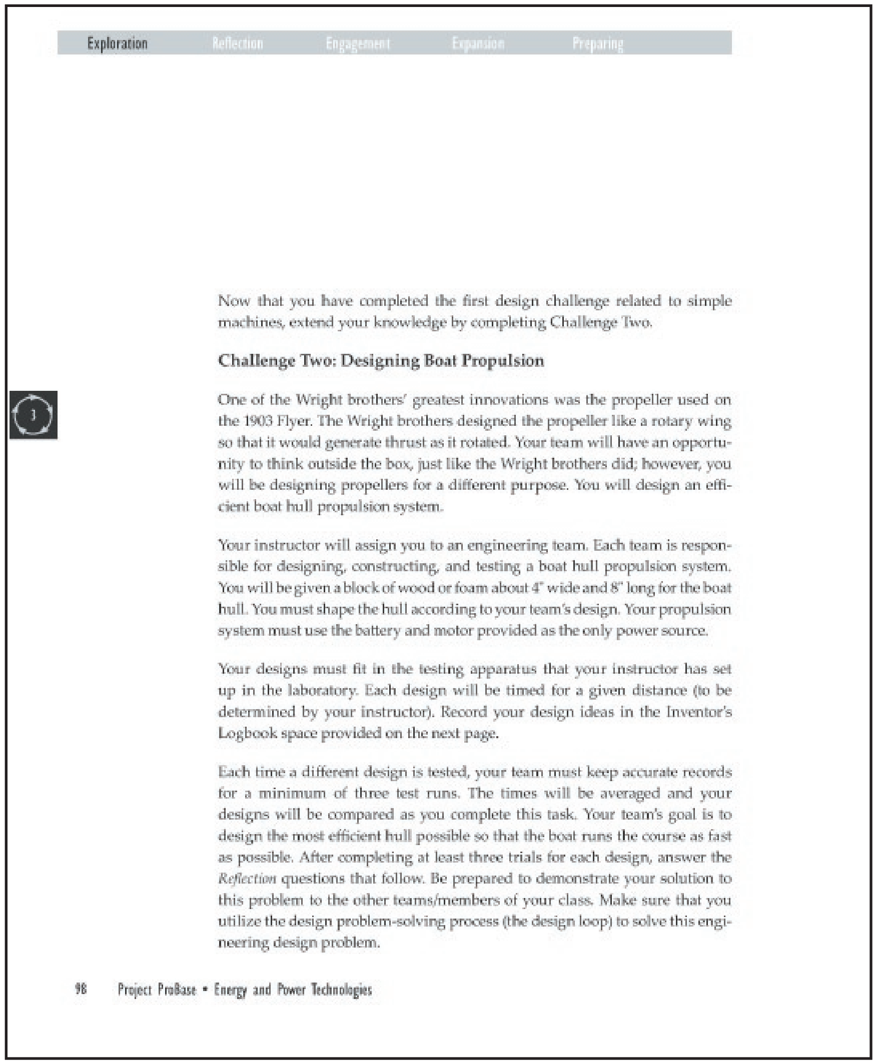
When your team has completed its device and is prepared to test it, notify your instructor and ask him/her to conduct a safety check. Your instructor may wish to test all devices at the same time.

After testing is complete, move on to Challenge Two and the *Reflection* that follows this additional challenge. Make certain that you retain all materials, drawings, and sketches during Challenge One as you will need these later.

Notes:

Students are required to complete the following for Challenge Two:

Each team is responsible for designing, constructing, and testing a boat hull and propulsion system. The designs must fit in the testing apparatus that you have set up in the laboratory. Each design will be timed for a given distance (to be determined by you). For an example design of a boat hull, see page AH in the Appendix of the Instructor's Guide.



Exploration Reflection Engagement Expansion Preparing

Now that you have completed the first design challenge related to simple machines, extend your knowledge by completing Challenge Two.

Challenge Two: Designing Boat Propulsion

One of the Wright brothers' greatest innovations was the propeller used on the 1903 Flyer. The Wright brothers designed the propeller like a rotary wing so that it would generate thrust as it rotated. Your team will have an opportunity to think outside the box, just like the Wright brothers did; however, you will be designing propellers for a different purpose. You will design an efficient boat hull propulsion system.

Your instructor will assign you to an engineering team. Each team is responsible for designing, constructing, and testing a boat hull propulsion system. You will be given a block of wood or foam about 4" wide and 8" long for the boat hull. You must shape the hull according to your team's design. Your propulsion system must use the battery and motor provided as the only power source.

Your designs must fit in the testing apparatus that your instructor has set up in the laboratory. Each design will be timed for a given distance (to be determined by your instructor). Record your design ideas in the Inventor's Logbook space provided on the next page.

Each time a different design is tested, your team must keep accurate records for a minimum of three test runs. The times will be averaged and your designs will be compared as you complete this task. Your team's goal is to design the most efficient hull possible so that the boat runs the course as fast as possible. After completing at least three trials for each design, answer the *Reflection* questions that follow. Be prepared to demonstrate your solution to this problem to the other teams/members of your class. Make sure that you utilize the design problem-solving process (the design loop) to solve this engineering design problem.

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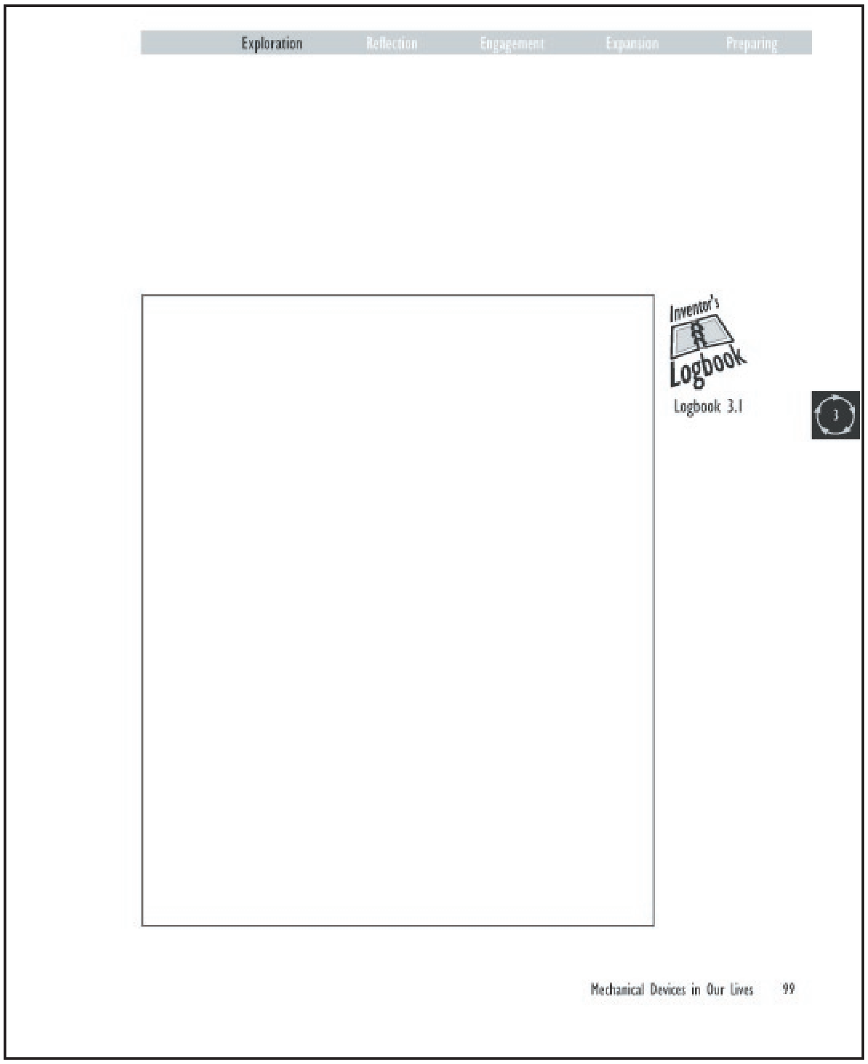
Exploration Reflection Engagement Expansion Preparing

Inventor's Logbook

Logbook 3.1

3

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Teaching tips

The concept of circular motion or angular velocity can be discussed prior to the completion of Challenge Two. An object (i.e., a propeller) going around in a circular path at a constant linear speed has acceleration (a change in velocity). The velocity or speed in a given direction (displacement/time) is always changing, because the direction of the object is always changing. Acceleration can be calculated by subtracting the original velocity (V_o) from the final velocity (V_f) and dividing that number by the time it took to travel between the two.

acceleration = $(V_f - V_o)$/Time

Teaching tips

You may decide to have students propose a materials list based on their propulsion systems according to the materials you provide. Either way, each team should be given a 4" x 8" block of wood or foam, batteries, and a motor.

Other possible materials include:

- Miscellaneous wood (craft sticks)
- Paper and cardboard stock
- Glue guns and glue
- Miscellaneous plastics
- Plastic chains
- Stop watch
- Battery holder

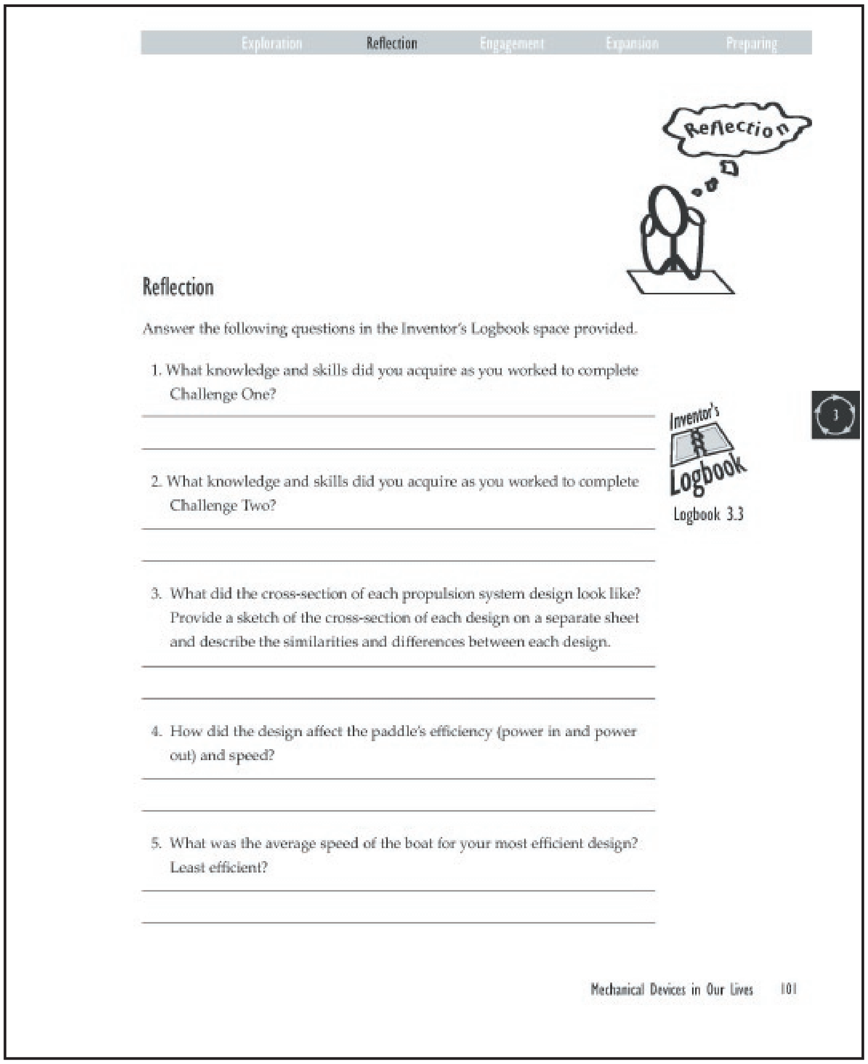
3

Testing the Device

When your team has completed its designs and is prepared to test them, notify your instructor and ask him/her to conduct a safety check. Your instructor may wish to test all devices at the same time. Create a table and record your test results in the Inventor's Logbook space provided.

Logbook 3.2

After testing is complete, move on to the *Reflection* that follows this challenge. Make certain that you retain all materials, drawings and sketches completed as a part of Challenge Two; you will need these later.


Exploration Reflection Engagement Expansion Preparing

Reflection

Answer the following questions in the Inventor's Logbook space provided.

1. What knowledge and skills did you acquire as you worked to complete Challenge One?

2. What knowledge and skills did you acquire as you worked to complete Challenge Two?

3. What did the cross-section of each propulsion system design look like? Provide a sketch of the cross-section of each design on a separate sheet and describe the similarities and differences between each design.

4. How did the design affect the paddle's efficiency (power in and power out) and speed?

5. What was the average speed of the boat for your most efficient design? Least efficient?

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Reflection

After completing both *Exploration* activities, have the students answer the following questions in their text and hold a class discussion:

1. What knowledge and skills did you acquire as you worked to complete Challenge One?

2. What knowledge and skills did you acquire as you worked to complete Challenge Two?

3. What did the cross-section of each paddle wheel design look like? Provide a sketch of the cross-section of each paddle wheel design in the space provided and describe the similarities and differences between each design.

4. How did the design affect the paddle's efficiency (power in and power out) and speed?

5. What was the average speed of the boat for your most efficient design? Least efficient?

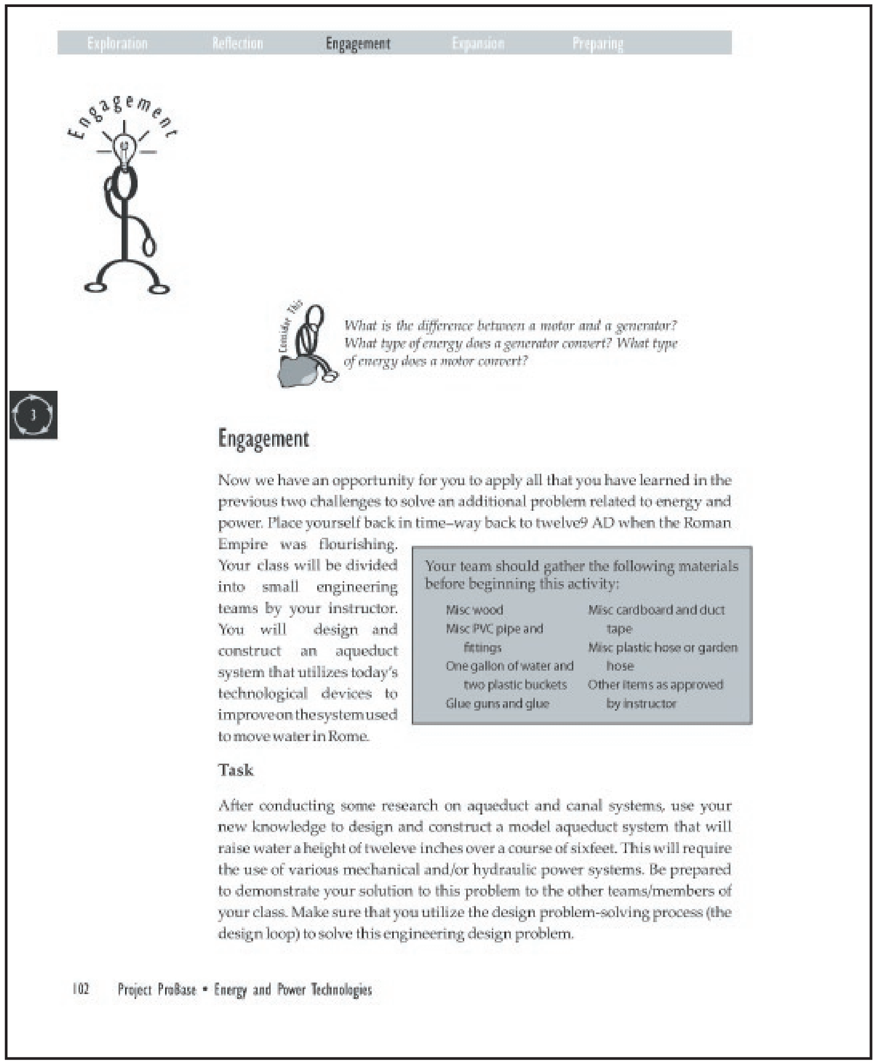
3

Engagement

At this phase of the learning cycle, students should be comfortable designing and building mechanical devices.

Teaching tips

When dividing the class into two teams, make sure that each team is comprised of students with varying degrees of knowledge and skills. Require students to follow the design loop and require the student teams to provide written documentation for each solution before materials are distributed—this will help you conserve materials and help the students clearly conceive ideas before beginning construction. Encourage your students to recycle and reuse materials whenever possible.



Exploration Reflection Engagement Expansion Preparing

Engagement

What is the difference between a motor and a generator? What type of energy does a generator convert? What type of energy does a motor convert?

Engagement

Now we have an opportunity for you to apply all that you have learned in the previous two challenges to solve an additional problem related to energy and power. Place yourself back in time–way back to twelve9 AD when the Roman Empire was flourishing. Your class will be divided into small engineering teams by your instructor. You will design and construct an aqueduct system that utilizes today's technological devices to improve on the system used to move water in Rome.

Your team should gather the following materials before beginning this activity:

- Misc wood
- Misc PVC pipe and fittings
- One gallon of water and two plastic buckets
- Glue guns and glue
- Misc cardboard and duct tape
- Misc plastic hose or garden hose
- Other items as approved by instructor

Task

After conducting some research on aqueduct and canal systems, use your new knowledge to design and construct a model aqueduct system that will raise water a height of tweleve inches over a course of sixfeet. This will require the use of various mechanical and/or hydraulic power systems. Be prepared to demonstrate your solution to this problem to the other teams/members of your class. Make sure that you utilize the design problem-solving process (the design loop) to solve this engineering design problem.

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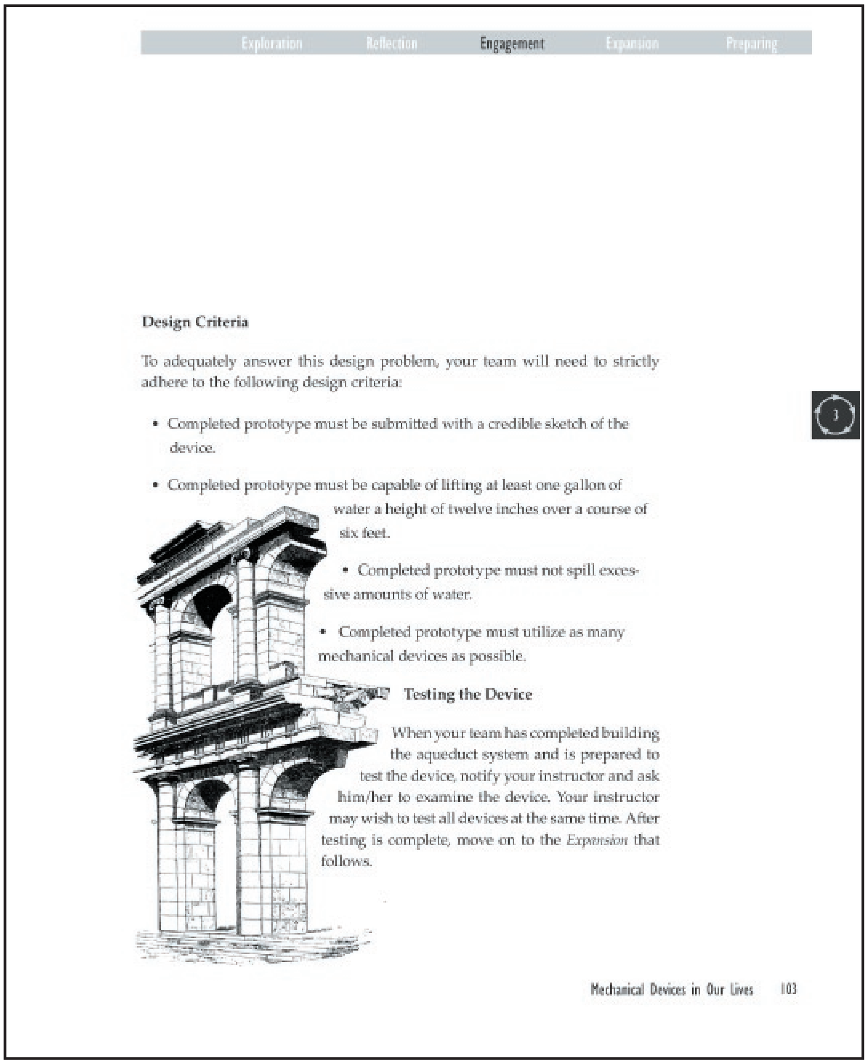
Students are required to complete the following task:

After conducting some research on aqueduct and canal systems, use your new knowledge to design and construct a model aqueduct system that will raise water a height of twelve inches over a course of six feet. This will require the use of various mechanical and/or hydraulic power systems. Be prepared to demonstrate your solution to this problem to the other teams/members of your class. Make sure that you utilize the design problem-solving process (the design loop) to solve this engineering design problem.



Exploration Reflection Engagement Expansion Preparing

Design Criteria

To adequately answer this design problem, your team will need to strictly adhere to the following design criteria:

- Completed prototype must be submitted with a credible sketch of the device.
- Completed prototype must be capable of lifting at least one gallon of water a height of twelve inches over a course of six feet.
- Completed prototype must not spill excessive amounts of water.
- Completed prototype must utilize as many mechanical devices as possible.

Testing the Device

When your team has completed building the aqueduct system and is prepared to test the device, notify your instructor and ask him/her to examine the device. Your instructor may wish to test all devices at the same time. After testing is complete, move on to the *Expansion* that follows.

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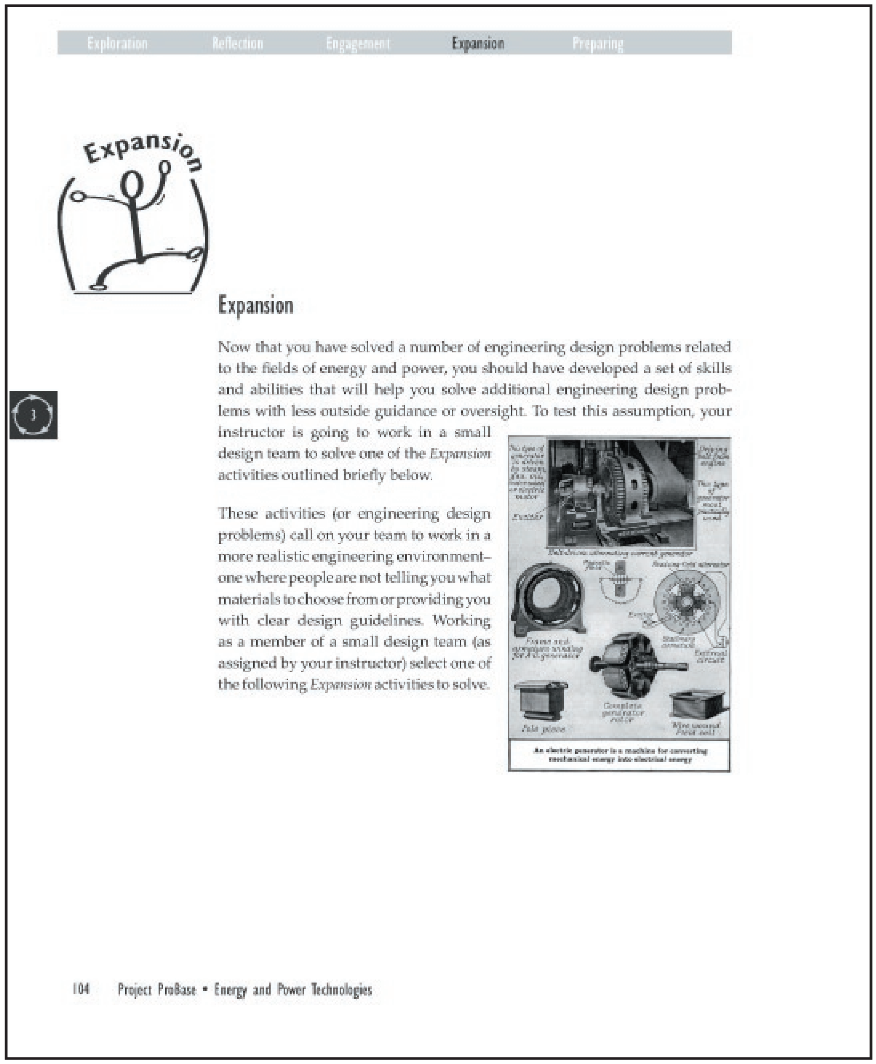
Design Criteria

To adequately answer this design problem, your team will need to strictly adhere to the following design criteria:

- Completed prototype must be submitted with a credible sketch of the device.
- Completed prototype must be capable of lifting at least one gallon of water a height of twelve inches over a course of six feet.
- Completed prototype must not spill excessive amounts of water.
- Completed prototypes must utilize as many mechanical devices as possible.

Expansion

Although not required, these *Expansion* activities are designed to cause teams to delve deeper into the concepts explored in this learning cycle.


Exploration Reflection Engagement Expansion Preparing

Expansion

Expansion

Now that you have solved a number of engineering design problems related to the fields of energy and power, you should have developed a set of skills and abilities that will help you solve additional engineering design problems with less outside guidance or oversight. To test this assumption, your instructor is going to work in a small design team to solve one of the *Expansion* activities outlined briefly below.

These activities (or engineering design problems) call on your team to work in a more realistic engineering environment–one where people are not telling you what materials to choose from or providing you with clear design guidelines. Working as a member of a small design team (as assigned by your instructor) select one of the following *Expansion* activities to solve.

An electric generator is a machine for converting mechanical energy into electrical energy

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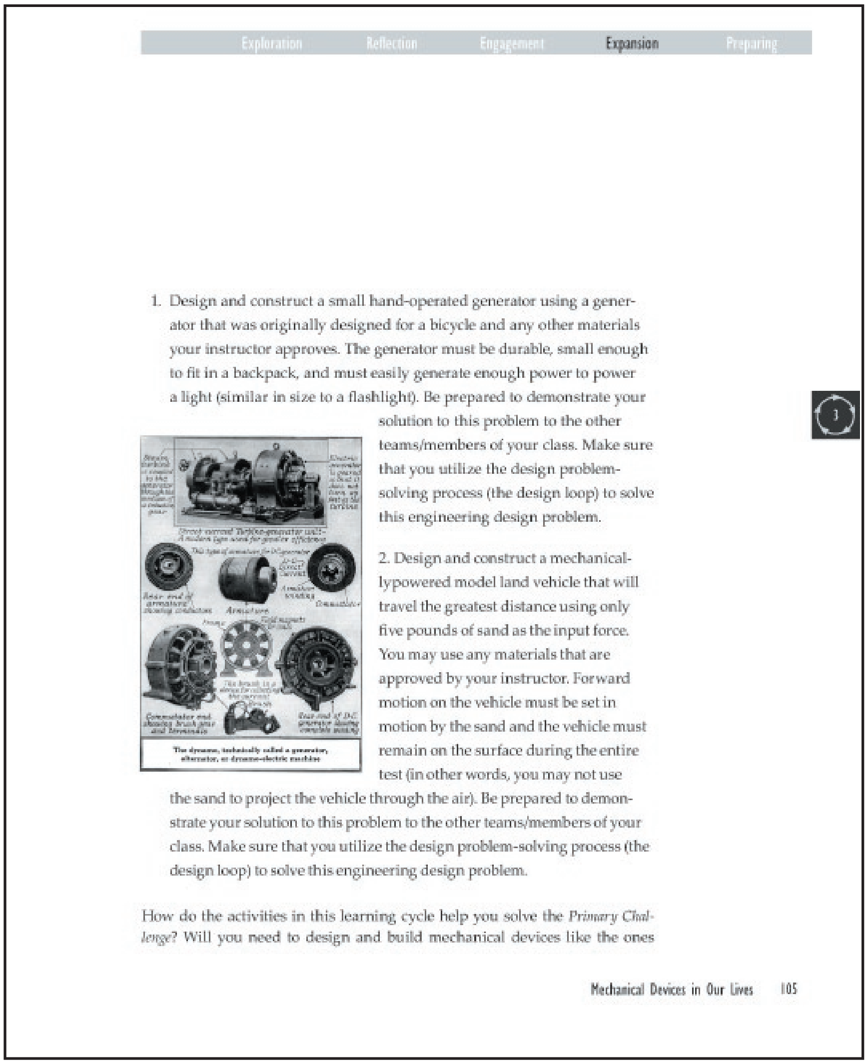
> **Teaching Tips**
>
> You will note that a detailed materials list is not provided for the *Expansion* activity. Teams should determine their own needs, decide upon the supplies that will be needed, and develop avenues for procuring these materials and supplies. You can ask the students to procure their own supplies and materials, ask the teams to provide you with a purchase list, or ask students to work from materials, equipment, and supplies available in your laboratory. Encourage your students to recycle and reuse materials whenever possible.

> **Teaching Tips**
>
> Make sure to emphasize the importance of utilizing the design problem solving process (the design loop) to solve these engineering design problems.

Now that the students have solved a number of engineering design problems related to the fields of energy and power, they should be able to solve additional engineering design problems with less outside guidance or oversight. To test this assumption, assign the students to work in a small design team to solve one of the *Expansion* activities outlined briefly on the next page. These activities (or engineering design problems) call on



1. Design and construct a small hand-operated generator using a generator that was originally designed for a bicycle and any other materials your instructor approves. The generator must be durable, small enough to fit in a backpack, and must easily generate enough power to power a light (similar in size to a flashlight). Be prepared to demonstrate your solution to this problem to the other teams/members of your class. Make sure that you utilize the design problem-solving process (the design loop) to solve this engineering design problem.

The dynamo, technically called a generator, alternator, or dynamo-electric machine

2. Design and construct a mechanicallypowered model land vehicle that will travel the greatest distance using only five pounds of sand as the input force. You may use any materials that are approved by your instructor. Forward motion on the vehicle must be set in motion by the sand and the vehicle must remain on the surface during the entire test (in other words, you may not use the sand to project the vehicle through the air). Be prepared to demonstrate your solution to this problem to the other teams/members of your class. Make sure that you utilize the design problem-solving process (the design loop) to solve this engineering design problem.

How do the activities in this learning cycle help you solve the *Primary Challenge*? Will you need to design and build mechanical devices like the ones

teams to work in a more realistic engineering environment—where materials are not listed or where clear design guidelines are not provided. Either assign or allow teams to select from one of the following design problems:

1. Design and construct a small hand-operated generator using a generator that was originally designed for a bicycle and any other materials your instructor approves. The generator must be durable, small enough to fit in a backpack, and must easily generate enough power to power a light (similar in size to a flashlight). Students should be prepared to demonstrate their solution to other teams.
2. Design and construct a mechanically powered model land vehicle that will travel the greatest distance using only five pounds of sand as the input force. Forward motion on the vehicle must be set in motion by the sand and the vehicle must remain on the surface during the entire test (in other words, teams may not use the sand to project the vehicle through the air). Teams will need to be prepared to demonstrate their solutions to other teams in the class.

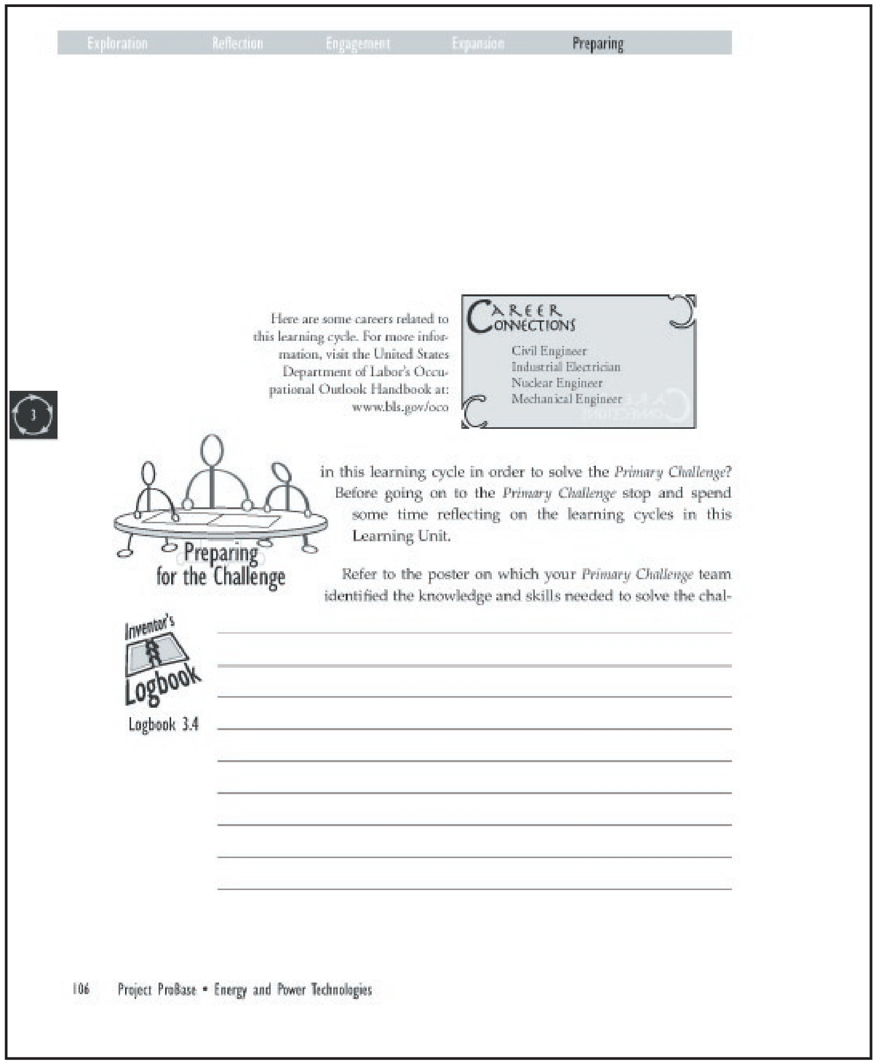
3

Teaching tips

If time allows, require the student teams to prepare and give a formal design presentation where they outline the merits and demerits of their various design solutions to these two problems.

Preparing for the Challenge

Now that the students have completed all the activities associated with this learning cycle, they need to consider the bigger picture of energy and power and how mechanical devices relate to the *Primary Challenge*.


Exploration Reflection Engagement Expansion **Preparing**

Here are some careers related to this learning cycle. For more information, visit the United States Department of Labor's Occupational Outlook Handbook at: www.bls.gov/oco

CAREER CONNECTIONS
Civil Engineer
Industrial Electrician
Nuclear Engineer
Mechanical Engineer

Preparing for the Challenge

in this learning cycle in order to solve the *Primary Challenge*? Before going on to the *Primary Challenge* stop and spend some time reflecting on the learning cycles in this Learning Unit.

Refer to the poster on which your *Primary Challenge* team identified the knowledge and skills needed to solve the chal-

Inventor's Logbook

Logbook 3.4

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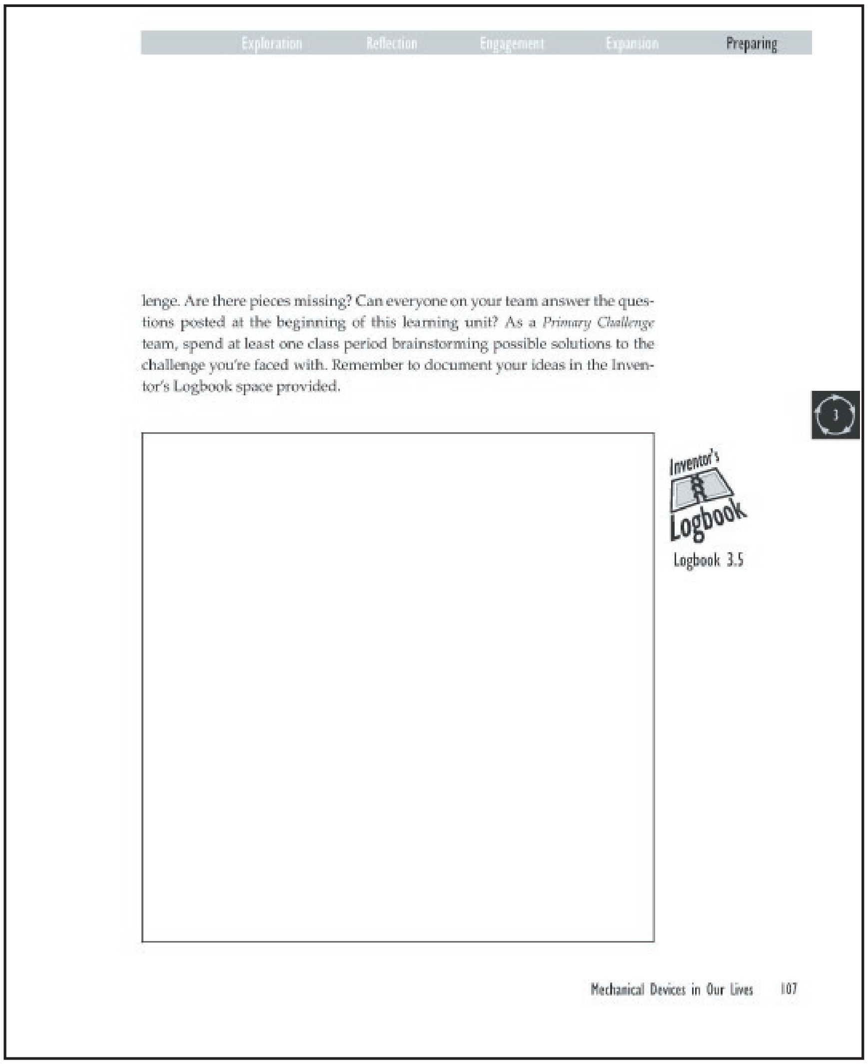
Teaching Tips

Discuss the following questions with your students:

- How do the activities in this learning cycle help you solve the *Primary Challenge*?
- Will you need to design and construct mechanical devices like the ones in this learning cycle in order to solve the *Primary Challenge*?

Provide time for students to meet in their *Primary Challenge* teams to review the poster they created at the beginning of this Learning Unit. Have them identify what they now know and decide if there is anything else that they need to explore before beginning the *Primary Challenge*. Remind students to document their ideas in the Inventor's Logbook spaces provided in their text.

After they have had time to complete this task, they should be directed to focus on their solution to the *Primary Challenge* for the time remaining for this Learning Unit.


Exploration Reflection Engagement Expansion Preparing

lenge. Are there pieces missing? Can everyone on your team answer the questions posted at the beginning of this learning unit? As a *Primary Challenge* team, spend at least one class period brainstorming possible solutions to the challenge you're faced with. Remember to document your ideas in the Inventor's Logbook space provided.

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Student Assessment

An assessment rubric has been developed for the *Exploration* and *Engagement* activities. Feel free to change this rubric to better suit your particular needs. In addition, it will be your prerogative as to how you assess the answers to the questions and other required tasks that students placed in their Inventor's Logbook.

Mechanical Devices in Our Lives

Element	Criteria				Points
	4	3	2	1	
Exploration Simple Machines	The device successfully used all six simple machines and lifted a person six inches from the floor.	The device successfully used all six simple machines and lifted a person two to five inches from the floor.	The device did not use all six simple machines, but lifted a person six inches from the floor.	The device did not use all six simple machines and did not lift a person off the floor.	
Propulsion System Design	Boat hull design and propulsion system exceed all criteria; no improvement needed.	Boat hull design and propulsion system meet all criteria; minor improvements needed; good effort.	Boat hull design and propulsion system meet some criteria; improvement needed.	Boat hull design and propulsion system does not meet criteria; major improvement needed; no effort displayed in design.	
Construction	Paddle wheel is fully functional, fits on boat; excellent quality construction.	Paddle wheel functions; high quality construction.	Paddle wheel construction needs significant improvement; does not function properly.	Paddle wheel does not function.	
Testing	All paddle wheel designs are tested multiple times; data is recorded neatly.	Paddle wheels designs are tested at least once; data is recorded.	One paddle wheel design is tested; data recording needs improvement.	Little or no effort shown to test paddle wheel or record data.	
Engagement	Aqueduct design and construction are of excellent, high quality; includes six mechanical devices.	Aqueduct design and construction are of good quality; includes four to five mechanical devices.	Aqueduct design and construction quality needs improvement; includestwo to three mechanical devices.	No effort shown in aqueduct design and construction; includes only one mechanical device.	
Function	Prototype lifts more than one gallon more than twelve inches; no spilling.	Prototype lifts one gallon; twelve inches; no spilling.	Prototype lifts less than one gallon less than twelve inches; spills a small amount of water.	Prototype does not lift water; spills.	
Testing	All aqueduct designs are tested multiple times; data is recorded neatly.	Aqueduct designs are tested at least once; data is recorded.	One aqueduct design is tested; data recording needs improvement.	Little or no effort shown to test aqueduct or record data.	
Inventor's Logbook Entries	Fully identifies the principles that underlie the simple machines and provided examples of where they are used.	Identifies most of the principles that underlie the simple machines and provided examples of where they are used.	Identifies few of the principles that underlie the simple machines and provided few examples of where they are used.	Does not identify the principles that underlie the simple machines and did not provide examples of where they are used.7	
				Total Points	

3

Appendix and Supplemental Materials

Appendix

Appendix

Project ProBase
Enduring Understandings & Essential Questions

Students will understand:

1. that **technological progression** is driven by a number of factors, including individual creativity, product and systems innovation, and human wants and needs.
    a. How are new technologies **developed and marketed**?
    b. What social, cultural, and political **pressures** lead to the need or want for new technologies?
    c. What are the specific **roles of professionals** involved in technological adaptation and change?
    d. What **factors** need to be in place for new technologies to be viable in the national and international marketplace?
    e. What are the fundamental **processes/principles** used to develop new technologies?

2. that **technological** development for the solution of a problem in one context can **spin-off** for use in a variety of often unrelated applications.
    a. How do **technologies migrate** from one context (or location) to another and what are the implications?
    b. What **roles** do the patent, trademark, and copyright laws play in the **dissemination of** technological **ideas**?
    c. How have technological innovations caused **paradigm shifts** throughout history and what are these major shifts?

3. that **technological change** can be positive and/or negative, and can have intended and/or unforeseen social, cultural, environmental, and political consequences.
    a. What are some of the unforeseen **consequences** of specific technological changes throughout history?
    b. How can a technology cause both good and harm and how do humans prepare for or respond to these **impacts**?

4. how **technological systems** work, the components of those systems, and how they fit into the larger technological, economic, and social systems.
    a. What are the systems and **subsystems** involved in the various contexts of technology?
    b. What are the key elements of the various technological **systems** and what are the **relationships** between these systems?
    c. How do various technological **systems influence** the economy, society, the environment, and culture?

5. that there are compelling and controversial **issues** associated with the acquisition, development, use, and disposal of **resources**.
    a. What kinds of **resources** are required in each of the eight technological contexts?
    b. What is the **relative value** of specific resources used in technological systems?
    c. To what extent have **resource** issues (acquisition, development, use, and disposal) **affected** the direction of technological **development**?
    d. What **resources** are **needed** to solve a specific design problem (people, information, materials, tools, capital, energy, time, technical ability)?

Students will understand:

6. that the complexities of technological **design** involve **trade-offs** among competing **constraints** and requirements, including engineering, economic, political, social, and environmental considerations.
    a. To what extent have **optimal designs** been achieved in the eight technological context areas?
    b. What are the key **factors** that cause designers to make decisions about trade-offs, limitations, and constraints when designing new products and systems? (**Micro Factors**)
    c. How can members of the public, politicians, or the state of the economy **influence** the design of new technological products and systems? (**Macro Factors**)
    d. How can **social values** and **principles** guide in the development of solutions to technological problems?

7. that **technological design** is a systematic **process** used to initiate and refine ideas, solve problems, and maintain products and systems.
    a. What are the five primary **methods** through which technological **problems** are **solved** and how do they differ (i.e., troubleshooting, research and development, experimentation, invention and innovation, design problem solving)?
    b. To what extent can design problems be approached through a series of generic procedures (the **design loop**)?
    c. What **design criteria** are typically considered when developing new technologies (i.e., marketability, safety, useability, reliability, cost, materials, etc.) and how do these influence the final product/system design?
    d. How are **decisions** made regarding **information** that should be discarded or ignored?
    e. How can the **attributes** of design and the **principles** of design aid in the development of quality solutions?
    f. How can the establishment of relationships, controlling variables, categorizing techniques, and making inferences aid in the **development** of **new** technological **designs**?

8. how to **evaluate** the benefits, limitations, and **risks** associated with existing and proposed technologies.
    a. How does a **risk/benefit analysis** aid the designer in addressing potential harmful effects prior to development?
    b. What are some important **ethical decisions** that should be considered when developing any new technology?
    c. Are all product/system **designs** created for the purpose of adding **social value**?
    d. How are ethical **considerations**, economic considerations, engineering realities, and political forces **balanced** during technological innovation?
    e. In what ways are technological needs and wants being **balanced** with long term environmental or social **consequences**?

9. how to **utilize** a variety of simple and complex **technologies**.
    a. How are technologies used to **control devices** and systems?
    b. How do technologies **communicate** with one another and provide information to humans?
    c. To what extent are technological systems and **devices controlled** by people and to what extent are they controlled by other technologies?
    d. How is technological **instrumentation** used to measure, calculate, manipulate, and predict the actions of technological devices and systems?

Energy and Power Technologies

Inventor's Logbook

Name: Date: Activity:

What do we know and need to know to solve the Primary Challenge

Place student questions here

Place student questions here

Energy and Power Technologies

Students will understand:

Enduring Understanding 3: that technological change can be positive and/or negative, and can have intended and/or unforeseen social, cultural, environmental, and political consequences.

a. What are some of the unforeseen consequences of specific technological changes throughout history?
b. How can a technology cause both good and harm, and how do humans prepare for, or respond to, these impacts?

Enduring Understanding 4: how technological systems work, the compoents of those systems, and how they fit into the larger technological, economic, and social systems.

a. What are the systems and subsystems involved in the various contexts of technology?
b. What are the key elements of the various technological systems and what are the relationships between these systems?

Enduring Understanding 6: that the complexities of technological design involve tradeoffs among competing constraints and requirements, including engineering, economic, political, social, and environmental considerations.

a. To what extent have optimal designs been achieved in the eight technological context areas?

Enduring Understanding 9: how to utilize a variety of simple and complex technologies.

a. How are technologies used to control devices and systems?
b. How do technologies communicate with one another and provide information to humans?
d. How is technological instrumentation used to measure, calculate, manipulate, and predict the actions of technological devices and systems?

Teamwork Rubric

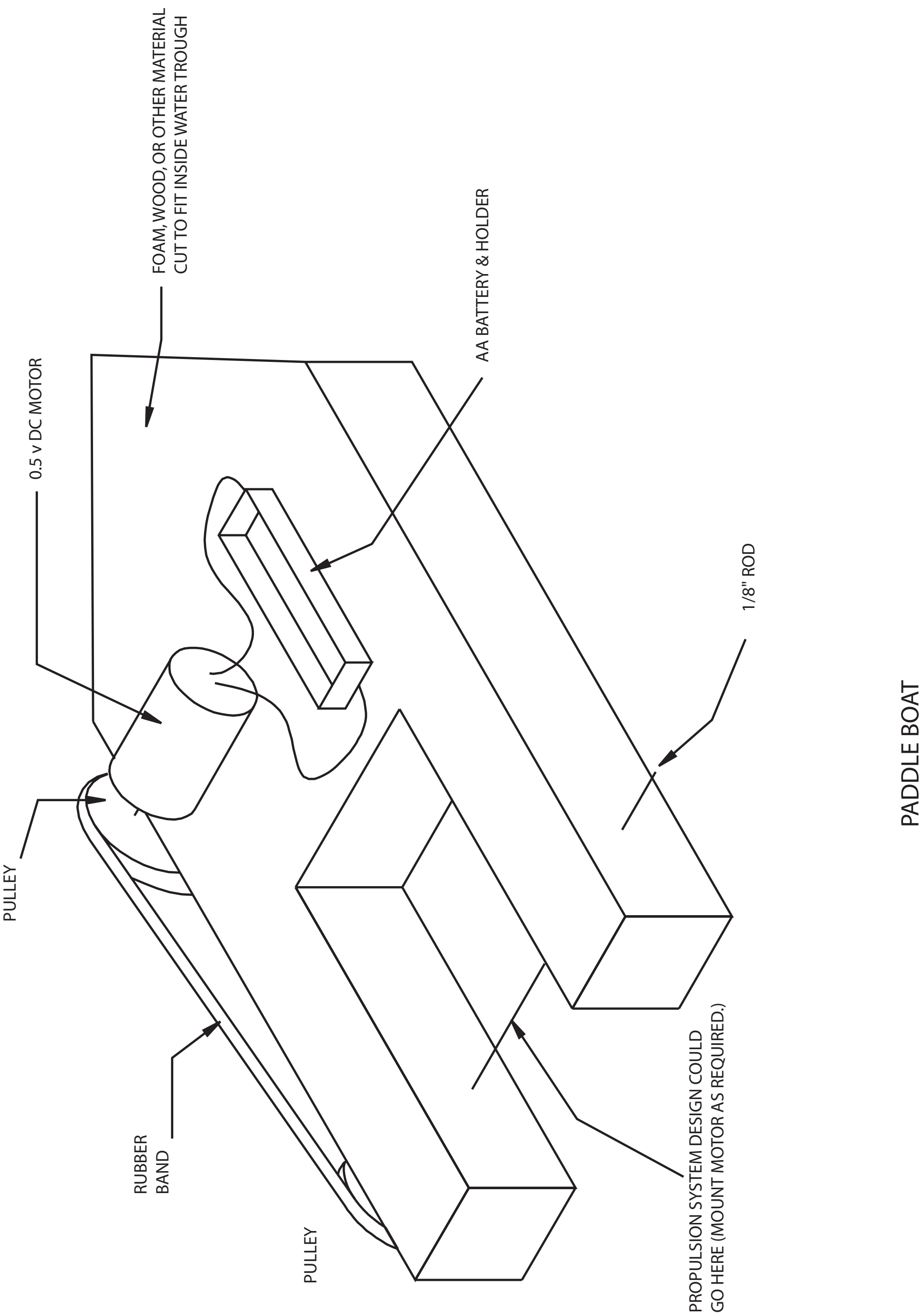
Observation of:	Criteria				Total Points
	4	3	2	1	
Helping - students offer assistance to one another	Consistently	Most of the time	Some of the time	None	
Listening - students work each others' ideas	Consistently	Most of the time	Some of the time	None	
Participating - students contribute to project/activity	Consistently	Most of the time	Some of the time	None	
Persuading - students exhange, defend, and rethink ideas	Consistently	Most of the time	Some of the time	None	
Questioning - students interact, discuss ,and pose questions to all team members	Consistently	Most of the time	Some of the time	None	
Respecting - students encourage and support ideas and efforts of others	Consistently	Most of the time	Some of the time	None	
Sharing - students offer ideas and report their findings to each other	Consistently	Most of the time	Some of the time	None	
Collaborative - overall team work	Consistently	Most of the time	Some of the time	None	
				Total Points	

Additional comments:

General Discussion Rubric — Energy and Power Technologies

Element	Criteria				Total Points
	4	3	2	1	
Interpretation - Understanding of issues, concepts, questions, ideas, topics	- Explores implications of issue and goes beyond it - Accurately states and identifies issues - Expresses relevant knowledge base based on own thoughts	- Explains aspects of issues - Accurately states issues - Expresses relevant knowledge base based on own thoughts	- Understands issues - States relevant factual, ethical, or definitional issue as a question -Expresses relevant knowledge base based on another's idea	- Does not state issues - Does not express relevant base knowledge	
Evidence - Support of comments	- Uses strong evidence relevant to specific issue - Draws connections with other relevant items and prior knowledge - Explains how it supports thoroughly	- Uses strong evidence relevant to specific issue - Explains how it supports	- Uses weak evidence relevant to specific issue - Briefly explains how it supports	- Does not provide evidence relevant to specific issue	
Listening and Responding - Commenting on others' ideas	- Invites comments from others - Compares own ideas to others' - Agrees/disagrees with specific parts and explains reasons - Reassesses own stance	- Invites comments from others - Explains reasons for agreeing or disagreeing - Adds to or challenges others' ideas	- Summarizes others' ideas - Agrees or disagrees with other ideas	- Only listens to others speak, does not respond - Copies other ideas - Disruptive	
Participation - Contribution to discussion	- Participates willingly - Takes a leadership role - Asks specific questions	- Participates willingly - Asks questions	- Participates only when called on	- Does not participate in class discussion	
				Total Points	

Boat Hull Design



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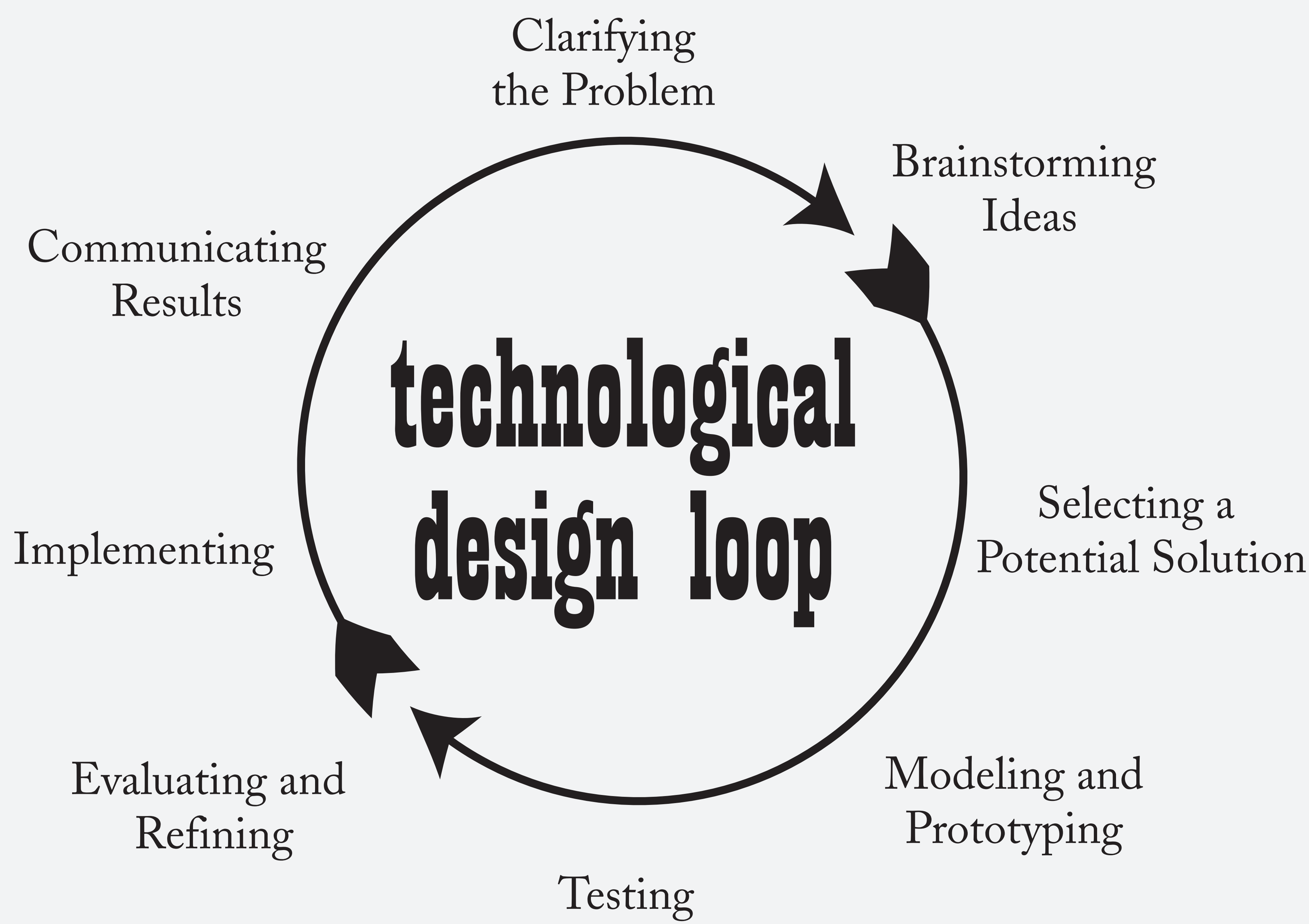

technological design loop
Clarifying the Problem
Brainstorming Ideas
Selecting a Potential Solution
Modeling and Prototyping
Testing
Evaluating and Refining
Implementing
Communicating Results

In addition to ***Energy and Power Technologies***, the ProBase curriculum series offers seven other Learning Units. The eight ProBase units can be used independently, in conjunction, or as an entire curriculum package. A brief description of each of the ProBase learning units follows. For more information contact the Center for Advancing the Teaching of Technology and Science.

Entertainment and Recreation Technologies

This unit unit explores technological entertainment and recreation systems and how their use impacts human leisure-time performance. The social, cultural, and environmental implications of entertainment and recreation technologies are also examined.

Medical Technologies

This unit provides an analysis of how medical technologies are used to increase the quality and length of human life, and how increased use of technology carries potential consequences, which require public debate. The tools and devices used to repair and replace organs, prevent disease, and rehabilitate the human body are also explored.

Agriculture and Related Biotechnologies

This unit provides an analysis of the various uses and ethical considerations of biotechnology. The unit also examines how agricultural technologies provide increased crop yields and allow adaptation to changing and harsh environments, enabling the growth of plants and animals for various uses.

Information and Communication Technologies

This unit examines how technology facilitates the gathering, manipulation, storage, and transmission of data and how this data can be used to create useful products. The unit also explores how communications systems can solve technological problems.

Construction Technologies

This unit explores the factors influencing the design and construction of various structures, including the infrastructural elements, community development factors, and environmental considerations. In addition, the unit provides experience with hands-on construction techniques and with modeling structures to scale.

Manufacturing Technologies

The unit explores the process of changing raw materials into finished products and how manufacturing affects the standard of living of various peoples. In addition, issues such as the maintenance of manufacturing efficiency, the effects of human consumption on manufacturing, and manufacturing's effects on the standard of living of various peoples are examined.

Transportation Technologies

This unit looks at the complex networks of interconnected subsystems that comprise transportation systems and the roles of these components in the overall functional process of transportation. The unit also provides an analysis of the improvements and the impacts of transportation technologies on the environment, society, and culture.